Vacuum Pumps and Components

Vacuum Pumping Systems

Analytical Systems

LEYBOLD-HERAEUS

LEYBOLD-HERAEUS VACUUM PRODUCTS INC.

Part Number 722-78-021 ■ Edition B

TMP/NT-50
Turbomolecular Pump & Frequency Converter
MANUAL

ITN-13.9

MP MASTER
MA29107

LIMITED WARRANTY

Seller warrants to the original purchaser that the equipment to be delivered pursuant to this Agreement will be as described herein and will be free from defects in material or workmanship. Minor deviations which do not affect the performance of the equipment shall not be deemed to constitute either a failure to conform to the specifications or a defect in material or workmanship.

This warranty shall extend for a period of twelve (12) months from the initial date of shipment. Should any failure of conformity to this warranty appear within twelve (12) months from the initial date of shipment, Seller shall, upon immediate notification of such alleged failure and substantiation that the equipment has been operated and maintained in accordance with Seller's recommendations and standard industry practices, correct such defects by suitable repair or replacement at its own expense.

Seller's liability under this warranty shall cease if any major repairs to or any replacement or modification of the equipment is made by any person other than Seller's personnel or persons working under the supervision of Seller's personnel, unless authorized by Seller in writing. Further, the warranty shall cease unless the Buyer has operated the equipment in strict compliance with operating instructions and manuals, if any, provided for the equipment, and unless Buyer operates the equipment in normal use and with proper maintenance.

If the equipment contains components from another manufacturer and are subject to the manufacturer's warranty, then Seller's liability shall be limited to the extent of the warranty which Seller received from the manufacturer or supplier of the equipment component parts. Seller's liability shall be no greater than the liability of the manufacturer or supplier as determined by a final judgment by the Buyer against the manufacturer or supplier of such components. Seller will cooperate with Buyer in such legal action but at Buyer's expense.

THIS WARRANTY IS EXPRESSLY IN LIEU OF ANY AND ALL REPRESENTATIONS AND WARRANTIES, EXPRESS OR IMPLIED, INCLUDING ANY WARRANTY OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR OTHER WARRANTY OF QUALITY, EXCEPT THE WARRANTY OF TITLE. THIS WARRANTY CONSTITUTES THE EXCLUSIVE REMEDY, and shall not be deemed to have failed of its essential purpose so long as Seller is willing and able to correct defects covered by the warranty in the manner prescribed. The sole purpose of the exclusive remedy shall be to provide Buyer with free repair and/or replacement in the manner and for the time period provided herein.

The entire agreement between the parties is embodied in this writing, which constitutes the final expression of the parties, and it is the complete and exclusive statement of the terms of the agreement. No other warranties are given beyond those set out in this writing.

LIMITATION OF LIABILITY. SELLER SHALL NOT, UNDER ANY CIRCUMSTANCES, BE LIABLE FOR DIRECT OR INDIRECT, SPECIAL DAMAGES, INCIDENTAL OR CONSEQUENTIAL, such as but not limited to, loss of profits, damage to or loss of other property, downtime costs of the equipment, delay expenses, overhead or capital costs, claims of Buyer's customers or activities dependent upon the equipment.

Except to the extent provided in the LIMITED WARRANTY, Seller shall not be liable for any claim or loss arising out of or related to this agreement or the equipment provided pursuant thereto, whether such claim allegedly arises or is based on contract, warranty, tort (including negligence), strict liability in tort or otherwise. Liability shall not in any event exceed the cost of the equipment upon which such liability is based.

SEVERABILITY. If any portion or clause of this agreement is held invalid or unenforceable as to any person or under any circumstances, the invalidity or lack of application shall not impair or affect the other provisions and the application of those provisions which can be given effect without the invalid or unenforceable provision or application. With this intention, the provisions of this agreement are declared to be severable.

WARNING

The TURBOTRONIC NT-50 Frequency Converter contains potentially lethal voltages and should only be serviced by qualified technicians.

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CONTENTS

Section	Title	Page
Table I.	TURBOVAC® TMP-50 Specifications	vii
Table II.	TURBOTRONIC NT-50 Specifications	viii
Table III.	Ordering Information	ix
Table IV.	Dimensional Data	x
Index		Last
SECTION 1 -	INTRODUCTION	1-1
1.1	SCOPE OF MANUAL	1-1
1.2	WARNINGS, CAUTIONS, AND NOTES	1-1
1.3	GENERAL DESCRIPTION	1-2
1.4	TMP-50 ACCESSORIES	1-3
1.4.1	Bakeout Jacket	1-3
1.4.2	Air Cooling Unit	1-4
1.4.3	Water Cooling Unit	1-4
1.4.4	Automatic Venting Valve	1-5
1.4.5	Intermediate Venting Flange	1-6
1.4.6	Vibration Damping Bellows	1-7
1.5	NT-50 OPTIONAL EQUIPMENT	1-7
SECTION 2 -	UNPACKING AND INSPECTION	2-1
2.1	GENERAL INFORMATION	2-1
2.2	UNPACKING AND INSPECTION	2-1
2.3	ADDITIONAL MATERIAL	2-2
SECTION 3 -	INSTALLATION	3-1
3.1	GENERAL INFORMATION	3-1
3.2	PRELIMINARY INSTALLATION CONSIDERATIONS	3-1
3.3	NT-50 INSTALLATION	3-3
3.3.1	AC Voltage and Fuse Selection	3-3
3.3.2	Converter Cooling	3-5

CONTENTS (Continued)

Section	Title	Page
SECTION 3 - INSTALLATION (Continued)		
3.3.3	Converter Mounting	3-5
3.3.4	Converter Rear Panel Terminal Block Wiring	3-7
3.3.4.1	Initial Wiring	3-7
3.3.4.2	Remote Start/Stop Wiring	3-7
3.3.4.3	Remote Normal Operation Sensing	3-8
3.3.5	Grounding	3-8
3.3.6	Pump and Converter Interconnection	3-10
3.3.7	Checking Pump Motor Direction of Rotation	3-11
3.4	TMP-50 INSTALLATION	3-14
3.4.1	Intake Port Connection	3-15
3.4.2	Exhaust Port Connection	3-16
3.4.3	Turbopump Cooling	3-17
3.4.3.1	Air-Cooling Unit Installation	3-18
3.4.3.2	Water-Cooling Unit Installation	3-18
3.4.4	Automatic Venting Valve Installation	3-19
3.4.5	Bakeout Jacket Installation	3-21
SECTION 4 - OPERATION		4-1
4.1	GENERAL INFORMATION	4-1
4.2	NT-50 FRONT PANEL CONTROLS AND INDICATORS	4-1
4.3	STARTING	4-2
4.4	OPERATION	4-4
4.4.1	Precautions	4-4
4.4.2	Overloads	4-4
4.4.3	Power Failure	4-4
4.4.4	Overtemperature	4-5
4.4.5	Restarting after an Interruption of Operation	4-5
4.5	STOPPING	4-6
4.6	VENTING	4-7
4.7	BAKE-OUT (CF FLANGE ONLY)	4-8
SECTION 5 - MAINTENANCE AND ADJUSTMENTS		5-1
5.1	GENERAL INFORMATION	5-1
5.2	PREVENTIVE MAINTENANCE	5-1

CONTENTS (Continued)

Section	Title	Page
SECTION 5 - MAINTENANCE AND ADJUSTMENTS (Continued)		
5.3	TMP-50 CLEANING	5-2
5.4	TMP-50 DISASSEMBLY/REASSEMBLY	5-6
5.4.1	Tools and Materials Required	5-6
5.4.2	Turbopump Dismounting and Wire-Mesh Inlet Screen Removal	5-7
5.4.3	Motor Housing Removal	5-8
5.4.4	Pump Housing Removal and Stator Package Disassembly	5-9
5.4.5	Rotor/Spindle Assembly Replacement	5-10
5.4.5.1	Rotor/Spindle Assembly Spare Parts and Accessories	5-10
5.4.5.2	Rotor/Spindle Assembly Removal	5-12
5.4.5.3	Rotor/Spindle Assembly Installation	5-14
5.4.5.4	Rotor Alignment	5-16
5.4.6	Stator Package and Pump Reassembly	5-17
5.4.7	Turbopump Running Tests	5-21
5.4.7.1	Run-Up Test	5-21
5.4.7.2	Leak Test	5-21
5.4.7.3	Venting Test	5-22
5.5	NT-50 DISASSEMBLY	5-23
5.6	NT-50 ADJUSTMENTS	5-24
5.6.1	+10 V Switching Power Supply Voltage Adjustment (P1)	5-26
5.6.2	+7.5 V Reference Adjustment (P2)	5-26
5.6.3	Pump Overtemperature Trip Point Adjustment (P3)	5-27
5.6.4	Maximum Drive Frequency Adjustment (P1)	5-29
5.6.5	Pump Speed Monitor Pulse Width Adjustment (P2)	5-30
SECTION 6 - DETAILED DESCRIPTION		6-1
6.1	TMP-50 OPERATING PRINCIPLE	6-1
6.2	TMP-50 CONSTRUCTION	6-2
6.3	FREQUENCY CONVERTER BASIC FUNCTIONS	6-4
6.4	NT-50 OPERATING PRINCIPLES	6-6
6.5	NT-50 CIRCUIT DESCRIPTIONS	6-12
6.5.1	Power Supply and Signal Generation Board	6-12
6.5.1.1	Power Supplies	6-12
6.5.1.2	Intermediate DC Voltage Monitor	6-15
6.5.1.3	Current Limiter	6-16
6.5.1.4	Pump Speed and Temperature Detectors	6-17
6.5.1.5	Temperature Dectector Enable Delay	6-19
6.5.1.6	Pulse Width Modulator	6-19

LEYBOLD-HERAEUS

CONTENTS (Continued)

Section	Title	Page
SECTION 6 - DETAILED DESCRIPTION (Continued)		
6.5.1.7	Three Phase Logic Generator	6-21
6.5.1.8	Remote Control and Remote Normal Operation Sensing	6-22
6.5.2	Control and Status Indication Board	6-23
6.5.2.1	Drive/Measure Interval Clock	6-24
6.5.2.2	Start/Stop Latch	6-25
6.5.2.3	Output Disable Control	6-26
6.5.2.4	Pump Speed to Current Converter	6-27
6.5.2.5	Pump Speed Monitor and Status Indication	6-28
6.5.2.6	Drive Frequency Clock	6-30
6.5.2.7	Slip Dependent Voltage Regulator	6-31
6.5.2.8	Overtemperature Failure Latch	6-33
6.5.3	Six-Step Inverter Board	6-34
SECTION 7 - TROUBLESHOOTING		7-1
SECTION 8 - PARTS LISTS AND DIAGRAMS		8-1
8.1	GENERAL INFORMATION	8-1
8.2	PART ORDERING INFORMATION	8-1
8.3	TMP-50 PARTS LIST	8-1
8.4	NT-50 PARTS LISTS AND SCHEMATICS	8-1

LIST OF FIGURES

Figure	Title	Page
SECTION 1 - INTRODUCTION		
1-1	Bakeout Jacket shown mounted around Pump's Intake Flange	1-3
1-2	Air Cooling Unit shown mounted on Pump	1-4
1-3	Water Cooling Unit shown mounted on Pump	1-4
1-4	Automatic Venting Valve	1-5
1-5	KF40/10 Reducing Cross used for Venting a KF Flanged Pump	1-6
1-6	Gauge Port Flange used for Venting an LF Flanged Pump	1-6
1-7	LF65/KF40/KF10 Reducing Cross used for Venting an LF Flanged Pump	1-6

LEYBOLD-HERAEUS

LIST OF FIGURES (Continued)

Figure	Title	Page
	SECTION 3 - INSTALLATION	
3-1	AC Voltage and Fuse Selection	3-4
3-2	19-Inch Rack Installation Frame with Cutout and Blank Front Panels	3-5
3-3	NT-50 Rear Panel Wiring	3-9
3-4	Pump and Converter Interconnection	3-11
3-5	Reversing Direction of Pump Motor	3-13
3-6	Typical Pumping System Diagram	3-14
3-7	Air Cooling Unit Installation	3-18
3-8	Water Cooling Unit Installation	3-19
3-9	Automatic Venting Valve mounted to an LF65 TMP50 using a Gauge Port Flange	3-20
	SECTION 4 - OPERATION	
4-1	NT-50 Front Panel Controls and Indicators	4-1
4-2	Safe High Vacuum Side Venting - Pressure Rise vs. Venting Time	4-7
	SECTION 5 - MAINTENANCE AND ADJUSTMENTS	
5-1	TMP-50 Exploded View	5-3
5-2	TMP-50 Cleaning without Disassembly	5-4
5-3	Wire-Mesh Inlet Screen Removal	5-7
5-4	Motor Housing Removal	5-8
5-5	Pump Housing Removal and Stator Package Disassembly	5-11
5-6	Rotor/Spindle Assembly Removal	5-13
5-7	Rotor/Spindle Assembly Installation	5-15
5-8	Rotor Alignment	5-16
5-9	Stator Package and Pump Reassembly	5-19
5-10	NT-50 Disassembly	5-23
5-11	NT-50 Internal Controls	5-25
	SECTION 6 - DETAILED DESCRIPTION	
6-1	Side View of Three Rotor/Stator Stages	6-1
6-2	TMP-50 Cutaway View	6-3
6-3	NT-50 Printed Circuit Board Locations	6-6
6-4	Six-Step Induction Motor Drive, Simplified Schematic with Voltage and Current Waveforms	6-9
6-5	NT-50 Block Diagram	6-13
6-6	Clock "C2UD", "C2D1", "C2D2", and "C3D3" Timing and Polarity Relationships	6-24

LEYBOLD-HERAEUS

LIST OF FIGURES (Continued)

Figure	Title	Page
SECTION 8 - PARTS LISTS AND DIAGRAMS		
8-1	TMP-50 Part Locations	8-3
8-2	NT-50 Power Supply and Signal Generation Board, Part Locations	8-5
8-3	NT-50 Power Supply and Signal Generation Board, Schematic	8-5
8-4	NT-50 Control and Status Indication Board, Part Locations	8-7
8-5	NT-50 Control and Status Indication Board, Schematic	8-7
8-6	NT-50 Six Step Inverter Board, Part Locations	8-9
8-7	NT-50 Six Step Inverter Board, Schematic	8-9

LIST OF TABLES

Table	Title	Page
I	TURBOVAC TMP-50 Specifications	vii
II	TURBOTRONIC NT-50 Specifications	viii
III	Ordering Information	ix
IV	Dimensional Data	x
SECTION 7 - TROUBLESHOOTING		
7-1	Trouble Shooting Chart	7-3
SECTION 8 - PARTS LISTS AND DIAGRAMS		
8-1	TMP-50 Parts List	8-2
8-2	NT-50 Power Supply and Signal Generation Board Parts List	8-4
8-3	NT-50 Control and Status Indication Board Parts List	8-7
8-4	NT-50 Six Step Inverter Board Parts List	8-10

TABLE I. TURBOVAC® TMP-50 SPECIFICATIONS

	Intake Flange DN*	
	KF®40	LF65 or CF63
Pumping Speed (volume flow rate ltr/sec):		
for N_2	33	55
for He	36	48
for H_2	28	30
Compression Ratio:		
for N_2	2×10^7	
for He	5×10^2	
for H_2	10^2	
Ultimate Pressure (PNEUROP)	8×10^{-9} mbar	
Fore-Vacuum Pressure	10^{-2} to 10^{-3} mbar	
Rotational Speed	72,000 r.p.m.	
Start-Up Time	5 min.	
Fore-Vacuum Port Fitting	KF16	
Venting Port Fitting (CF63 Flanged Pumps only)	KF10	
Ambient Temperature, max.**	122°F (50°C)	
Bakeout Temperature, max. (at Intake Flange)	176°F (80°C)	
Mounting Position	In Any Desired Position	
Weight	3 to 4.4 lb (1.4 to 2 kg)	
Dimensions	See TABLE IV DIMENSIONAL DATA	
Recommended Backing Pump	TRIVAC® D1.6B or D2A	
Lubrication	Grease (Lifetime Lubricated)	

*ISO size DN = nominal width NW

**This maximum ambient temperature is for a non-baked pump, that is continuously operating at $<10^{-4}$ mbar without additional cooling. For a pump that is being baked out, the maximum ambient air temperature is 104°F (40°C).

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TABLE II. TURBOTRONIC NT-50 SPECIFICATIONS

Input Voltage (two ranges)	90-140 or 180-265 V AC, single phase
Input Frequency	40 to 400 Hz
Input Power:	
Maximum	45 Watts
Continous	18 Watts
Standby	3 Watts
Output Voltage (max.)	3 X 150 V
Output Frequency:	
Normal	1250 Hz
Range	200 to 1250 Hz
Voltage at Remote Control START/STOP Terminals	+5 V
Normal Operation Relay Contact Ratings	4 A at 250 V AC 120 W at 30 V DC
Fuse:	
for 90-140 V AC	T 1A/250 D
for 180-265 V AC	T 0.5A/250 D
Weight	3.3 lb (1.5 kg)
Dimensions	See TABLE IV DIMENSIONAL DATA

TABLE III. ORDERING INFORMATION

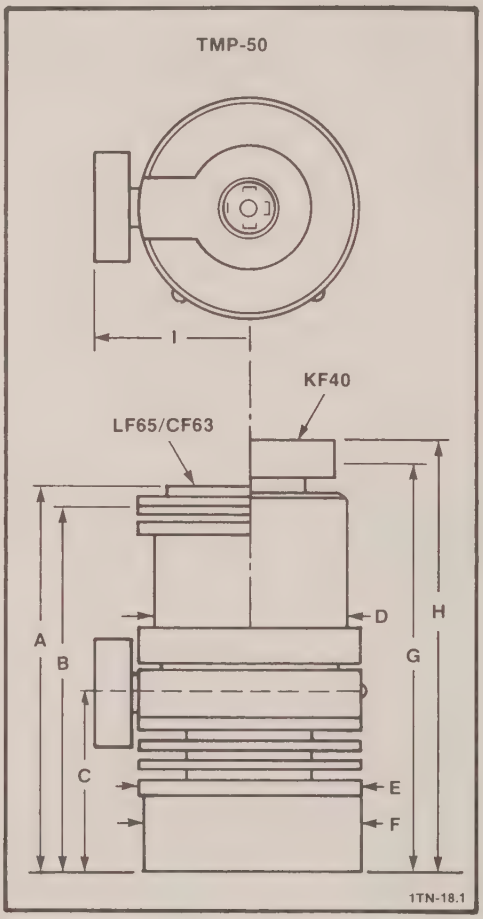
PUMP AND CONVERTER	Catalog Number
TMP-50 Turbomolecular Pump (order according to inlet flange):	
KF40 (Aluminum Housing)	85400
LF65 (Aluminum Housing)	85401
CF63 (Stainless Steel Housing)	85402
NT-50 Frequency Converter	85403-1
Pump Cable, 10 ft. (3 m)	200-29-979

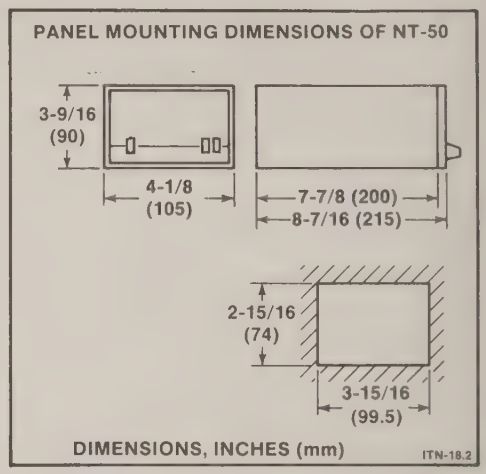
ACCESSORIES	
Bakeout Jacket (CF63 Flanged Pumps only)*	
115 V AC	85407
220 V AC	85404
Air Cooling Unit:	
115 V AC	85406-1
220 V AC	85405
Water Cooling Unit	85408
Vibration Damping Bellows:	On Request
Automatic Venting Valve, KF10**:	
115 V AC, Normally Open	98-273-012
115 V AC, Normally Closed	98-273-011
Intermediate Inlet Fitting for KF10 Venting Valve Connection:	
CF63 Flanged Pump - No Intermediate Fitting Required	
KF40 Flanged Pump - Use a KF40/KF10 Reducing Cross	18419
LF65 Flanged Pump - Use either a:	
Gauge Port Flange	28607
LF65/KF40/KF10 Reducer Cross	26857
Flange Adapter, LF65 to 3-inch ASA	98-278-0700

* Use of Bakeout Jacket may require additional pump cooling.

** Depending on inlet flange size, use of an Intermediate Inlet Fitting may be required to mount venting valve.

TABLE IV. DIMENSIONAL DATA





TMP-50 Dimensions, Inches (mm)

Flange Types	A	B	C	D	E	F	G	H	I
KF40	-	-	2 7/8 (73)	3 3/16 (81)	3 5/8 (92)	3 1/2 (89)	6 7/16 (164)	6 7/8 (174)	2 5/16 (59)
CF63	6 1/8 (155)	5 13/16 (147)	2 7/8 (73)	3 3/16 (81)	3 5/8 (92)	3 1/2 (89)	-	-	2 5/16 (59)
LF65	6 1/8 (155)	5 13/16 (147)	2 7/8 (73)	3 3/16 (81)	3 5/8 (92)	3 1/2 (89)	-	-	2 5/16 (59)

SECTION 1
INTRODUCTION

1.1 SCOPE OF MANUAL

This manual contains installation, operation, description, and service information for the TURBOVAC Model TMP-50 Turbomolecular Pump, and the TURBOTRONIK Model NT-50 Frequency Converter. These two units are designed to function together for the production of ultra-clean, hydrocarbon-free high vacuum.

Specifications and ordering information for the TMP-50 and NT-50 are contained in Tables I, II, and III, located at the front of this manual.

Before unpacking, installing, and operating the TMP-50 and NT-50, read Sections 2, 3, and 4 of this manual carefully. This will ensure that you understand what needs to be done prior to placing the pump and its converter into operation.

1.2 WARNINGS, CAUTIONS, AND NOTES

"WARNING" statements call attention to conditions, practices, or procedures which must be observed to avoid personal injury.

"CAUTION" statements contain information which must be followed to prevent damage to equipment.

"NOTES" contain information of special importance or interest.

1.3 GENERAL DESCRIPTION

WARNING

DO NOT use the TMP-50 for pumping oxidizers or higher than atmospheric concentrations of oxygen.

The Leybold-Heraeus TURBOVAC model TMP-50 Turbomolecular Pump can produce an ultra-clean, hydrocarbon-free vacuum at an ultimate pressure of 8×10^{-9} mbar. Other features of the TMP-50 are listed below:

- Grease lubricated bearings permit the pump to operate in any desired angular position, while retaining the advantages of single axial flow construction.

- Dynamic balancing of the pump's replaceable rotor/spindle assembly produces silent running with minimal vibration.

- The turbine and drive assembly with internal motor are mounted in an aluminum housing for KF and LF flanged pumps, while a stainless steel housing is used for CF flanged pumps.

- The pump motor is protected from overheating by a temperature detector circuit in the converter, which shuts down the pump if its motor exceeds a safe operating temperature limit.

- The top rotor blade of the turbine is located just below the high vacuum connection flange to minimize the loss of conductance due to the impedance of the intake port.

- A heat treated aluminum alloy is used for the rotor assembly.

- The complete drive assembly including bearings and motor is located in the fore-vacuum space.

The TURBOTRONIK model NT-50 Frequency Converter is designed to provide 3-phase, variable voltage, variable frequency power to the pump's induction motor. The pump is started and stopped by the converter's front panel START and STOP pushbuttons. Front panel POWER, ACCEL (acceleration), NORM (normal), and FAIL (failure) indicators show the status of the converter. A rear panel terminal block provides the means of connecting remote start/stop controls, and remote normal-operation-sensing devices.

Detailed descriptions of the TMP-50 and NT-50 are contained in Section 6 of this manual.

1.4 TMP-50 ACCESSORIES

The following are accessory items available for the TMP-50. Catalog numbers for these items are contained in Table III Ordering Information, located at the front of this manual.

1.4.1 BAKEOUT JACKET (CF Flange Only)

The optional Bakeout Jacket (Fig. 1-1) allows automatic controlled bakeout of a stainless steel, CF flanged TMP-50 when operational pressures of <10-7 mbar are required. This device is mounted around the pump's intake flange. Either a 115 or 220 VAC model can be ordered.

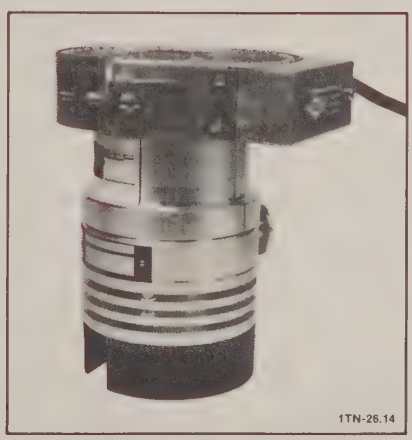


Figure 1-1. Bakeout Jacket shown mounted around Pump's Intake Flange

Bakeout Jacket installation information is contained in Section 3.4.5, while operating information is located in Section 4.7.

1.4.2 AIR COOLING UNIT

The optional Air Cooling Unit (Fig. 1-2) consists of a single fan mounted on vibration dampers. Either a 115 or 220 VAC model can be ordered.

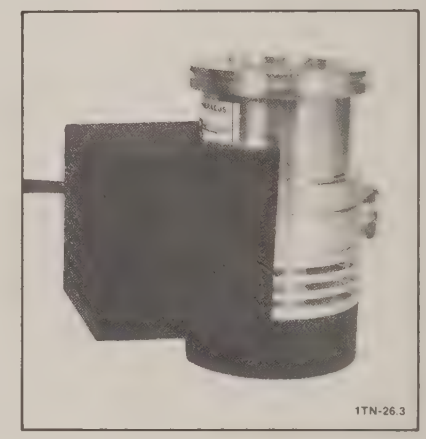


Figure 1-2. Air Cooling Unit shown mounted on Pump

The Air Cooling Unit should be used whenever the ambient temperature exceeds 122°F (50°C), or when operating pressures are higher than 10^{-4} mbar. This unit is also required when a pump is being continuously baked out. Note, however, that the maximum permissible ambient temperature for a pump during bakeout with air-cooling is 104°F (40°C).

The Air Cooling Unit's installation procedure is contained in Section 3.4.3.1.

1.4.3 WATER COOLING UNIT

The optional Water Cooling Unit (Fig. 1-3) is used whenever air-cooling of the pump is not permissible (i.e., fast pump-down cycles, ambient temperature too high).

This unit requires a source of clean tap water at a temperature of between 59 and 77°F (15 and 25°C) and at a pressure of between 40 and 90 psig.

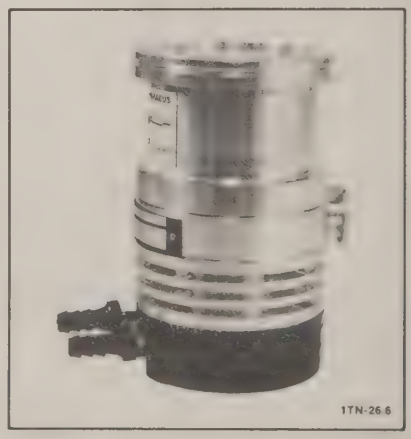


Figure 1-3. Water Cooling Unit shown mounted on Pump

The Water Cooling Unit's installation procedure is contained in Section 3.4.3.2.

1.4.4 AUTOMATIC VENTING VALVE

An Automatic Venting Valve (Fig. 1-4) is used to vent the pump immediately after being shut down. This device is an electromagnetic actuated valve which mounts on a KF10 flange. Normally-open and normally-closed valves are available. Note that normally-open valves close when energized, while normally-closed valves are opened when energized.

Figure 1-4. Automatic Venting Valve

The Automatic Venting Valve is connected into the pumping system such that when the pump is shut down, this valve will open and allow the venting gas to enter the pump while it is still rapidly rotating. This ensures very clean venting of the pump, eliminating entrainment of any residual hydrocarbons to the pumping system's high-vacuum side.

Automatic Venting Valve installation information is contained in Section 3.4.4, while information on turbopump venting is located in Section 4.6.

1.4.5 INTERMEDIATE VENTING FLANGE

When venting from the vacuum chamber is not possible, an Intermediate Venting Flange is required for the KF and LF flanged pumps. This intermediate flange is attached to the pump's high vacuum port. Note that the CF flanged pump has an integrated venting port located midway between its intake and exhaust ports.

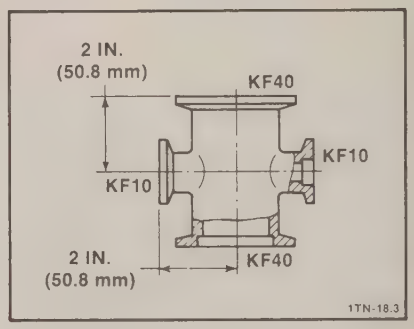


Figure 1-5. KF40/10 Reducing Cross used for Venting a KF Flanged Pump

For a KF flanged pump, the Intermediate Venting Flange consists of a KF40/10 Reducing Cross (Fig. 1-5) with one of its KF10 ports sealed off. A venting valve is then attached to the other KF10 port.

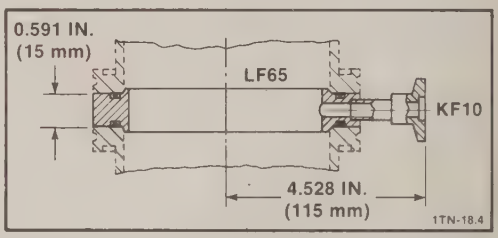


Figure 1-6. Gauge Port Flange used for Venting an LF Flanged Pump

For an LF flanged pump, the Intermediate Venting Flange consists of a Gauge Port Flange (Fig. 1-6), to which a venting valve can be mounted on its single KF10 port. An LF65/KF40/KF10 Reducing Cross (Fig. 1-7) can also be used if desired, on which both a venting valve and a high vacuum gauge tube can be mounted.

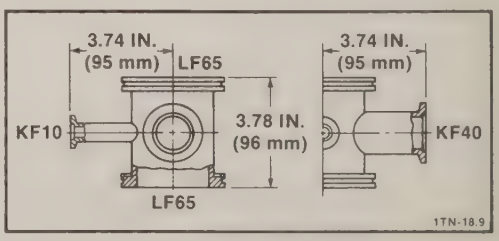


Figure 1-7. LF65/KF40/KF10 Reducing Cross used for Venting an LF Flanged Pump

1.4.6 VIBRATION DAMPING BELLOWS

The optional Vibration Damping Bellows is a flexible duct which is connected between the pump's high vacuum inlet and the outlet of the vacuum chamber. We recommend that bellows be used for connecting the TMP-50 to instruments highly sensitive to vibration, or to prevent external vibrations from being transmitted to the pump. Note that the TMP-50 is normally used without bellows because of its precision dynamic balance which produces a total vibration velocity of not more than 0.1 mm/second.

1.5 NT-50 OPTIONAL EQUIPMENT

The following optional equipment can be added to the frequency converter. Wiring information is contained in Section 3.3.4.

- o Remote START/STOP Switches -- Normally open and normally closed momentary pushbuttons or a single toggle switch can be used for the purpose of remotely starting and stopping the pump. Refer to Section 3.3.4.2.

- o Remote Normal Operation Device -- An indicating or control device (e.g., LED, lamp, or valve) can be turned on or off when the converter achieves normal operation. Refer to Section 3.3.4.3.

NOTES

SECTION 2
UNPACKING AND INSPECTION

2.1 GENERAL INFORMATION

This section includes instructions for unpacking the TMP-50 Turbomolecular Pump and the NT-50 Frequency Converter, and inspecting these items for shipping damage.

2.2 UNPACKING AND INSPECTION

Proceed as follows to unpack and check the TMP-50 and NT-50 for shipping damages as soon as you receive it, even though the equipment may not be needed right away.

1. Inspect the outside of each shipping container for visible damage. If damage is apparent, keep the shipping container and packing materials if internal damage is later found.

CAUTION

In the following step, do not remove any protective cover from the TMP-50 until the pump is ready for connection to the vacuum system. This ensures that the pump will not be damaged or become dirty.

2. Carefully unpack the TMP-50 and NT-50 and inspect for damage.

3. If you find any evidence of damage, proceed as follows:

   a. Save the shipping container, packing material, and damaged part for inspection.

   b. Notify the carrier that made the delivery within 15 days of delivery, in accordance with Interstate Commerce Commission regulations, and file a claim with the carrier for the damage.

      NOTE: All equipment is shipped F.O.B. from the factory; therefore, any damage in transit is the responsibility of the carrier.

   c. Contact the Order Services Department of Leybold-Heraeus in Export, PA or your nearest Leybold-Heraeus representative to order replacement parts.

2.3 ADDITIONAL MATERIAL

In addition to the turbopump and frequency converter, the following quantities of additional material are included with these units:

TMP-50 with LF Flange:

Qty.

1 - Wire-Mesh Inlet Screen
1 - LF65 Centering Ring, VITON O-Ring, and Outer Ring
2 - LF Flange Clamp
1 - KF16 Centering Ring with Buna-N O-Ring
1 - KF16 Clamp
1 - TMP/NT-50 Instruction Manual

TMP-50 with KF Flange:

Qty.

1 - Wire-Mesh Inlet Screen

1 - KF40 Centering Ring with Buna-N O-Ring

1 - KF40 Clamp

1 - KF16 Centering Ring with Buna-N O-Ring

1 - KF16 Clamp

1 - TMP/NT-50 Instruction Manual

TMP-50 with CF Flange:

Qty.

1 - Wire-Mesh Inlet Screen

1 - KF16 Centering Ring with Buna-N O-Ring

1 - KF16 Clamp

1 - TMP/NT-50 Instruction Manual

NT-50

Qty.

1 - Fuse, 1.0 A, for 90-140 V AC

2 - Fuse, 0.5 A, for 180-265 V AC

1 - 4 Conductor Pump Cable with Connectors, 10 ft. (3 m)

1 - Pump Connector Retaining Screw

1 - Pump Connector Gasket

1 - TMP/NT-50 Instruction Manual

NOTES

SECTION 3
INSTALLATION

3.1 GENERAL INFORMATION

This section contains information on how to install both the NT-50 Frequency Converter and the TMP-50 Turbomolecular Pump. Also included is a procedure which checks that the pump will be rotating in the correct direction, before the pump is installed.

3.2 PRELIMINARY INSTALLATION CONSIDERATIONS

The following information should be considered before you start to install or apply power to the frequency converter and turbopump.

1. The pump is shipped in a sealed PVC bag with moisture absorbent. Also, a protective cover is installed on the pump's intake port. Remove this material just before mounting the pump to your pumping system.

2. Ensure that the pump motor's direction of rotation is correct before installing the pump. Refer to Section 3.3.7.

3. When installing the pump within a magnetic field, ensure that the magnetic induction measured at the surface of the pump housing does not exceed 70 gauss [7 mT (militesla)] in a radial field. If this value is exceeded, the resulting eddy currents might heat up the rotor; therefore, suitable magnetic shielding of the pump will be necessary.

4. The TMP-50 was not specifically designed to pump oxidizers or higher than atmospheric concentrations of oxygen, nor was it designed to pump abrasive or highly corrosive products at high pressure. Please contact Leybold-Heraeus if you intend on pumping these gases.

5. The standard pump is radiation resistant up to 10^5 rad. If higher radiation resistance is required, please contact Leybold-Heraeus.

6. A two-stage rotary vane pump, such as the Leybold-Heraeus TRIVAC D2A, is required as a backing pump for the turbopump.

7. When pumping down large chambers, the chamber should be roughed down with the backing pump before starting the turbopump. In this situation, a separate roughing line is installed between the chamber and backing pump. Roughing the chamber in this manner will decrease the pumping time and also prevent the backstreaming of oil vapors from the backing pump up through the turbopump while it is at a standstill.

8. The installation of an adsorption trap in the foreline is recommended to limit the backstreaming of oil vapors from the backing pump into the turbopump.

9. The pump must be protected from heavy external shocks vibration. Use bellows or flexible tubing between the turbopump and its backing pump.

10. The pump can be mounted in any angular position directly by its intake flange to the vacuum system.

11. If the pump will be operated in ambient air temperatures that exceed 122°F (50°C), then the optional Air Cooling or Water Cooling Unit should be attached to the pump.

12. If the pump will be continuously operated between a pressure of 1.3 x 10^{-3} mbar (1.0 x 10^{-3} Torr) and its maximum rated pressure of 0.13 mbar (0.1 Torr), the rating of the backing pump or pumping system may need to be increased to accomodate the exceptionally high throughput of the turbopump. Contact Leybold-Heraeus for recommendations.

3.3 NT-50 INSTALLATION

The following procedures describe how to wire and install the NT-50 Frequency Converter.

3.3.1 AC VOLTAGE AND FUSE SELECTION

The NT-50 is normally shipped set up to operate from an AC line voltage of between 90 and 140 V AC. To ensure that the NT-50 is properly connected to operate from the line voltage that will be applied to the converter, or to change its input voltage range, proceed as follows:

WARNING

To avoid personal injury due to electrical shock, DO NOT plug the converter into an AC service outlet when the converter housing is removed during the following procedure.

1. Remove the converter from its housing (refer to Section 5.5 NT-50 Disassembly).

2. Locate connector STV1 on the bottom printed circuit board (Fig. 3-1). Then place this connector in one of the following positions according to the AC line voltage that will be applied to the converter:

   - o 90 to 140 V AC -- STV1 in LO position (Terminals 1 and 2)
   - o 180 to 265 V AC -- STV1 in HI position (Terminals 2 and 3)

3. Locate the AC line fuse on the bottom printed circuit board (Fig. 3-1). Then install one of the following fuses according to the AC line voltage that will be applied to the converter.

   - o 90 to 140 V AC -- 1 Ampere Fuse
   - o 180 to 265 V AC -- 0.5 Ampere Fuse

4. Reinstall the converter into its housing.

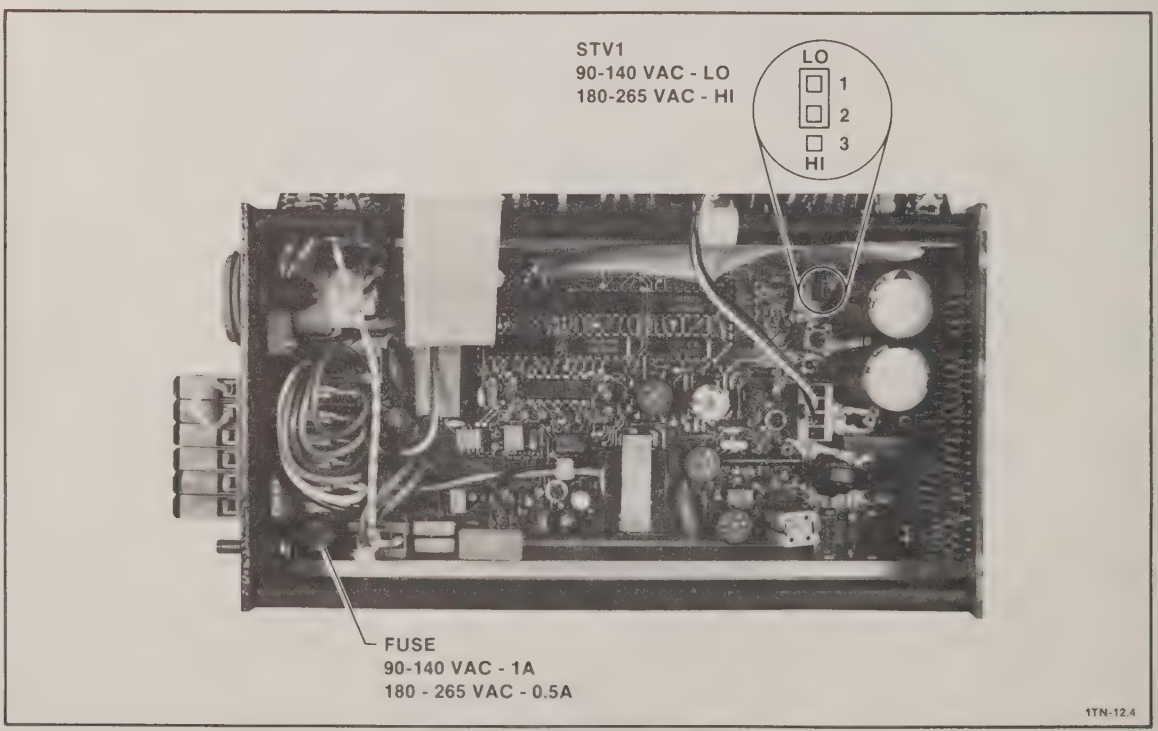


Figure 3-1. AC Voltage and Fuse Selection

3.3.2 CONVERTER COOLING

The NT-50 Frequency Converter depends primarily on convection cooling to maintain an acceptable internal operating temperature. This temperature is easily achieved if the air flow through the converter is not restricted and if ambient air temperatures do not exceed 113°F (45°C).

Excessive operating temperatures due to restricted air flow will void the converter's warranty, may result in premature failure of the converter, and will definitely degrade its reliability.

3.3.3 CONVERTER MOUNTING

The converter is supplied with a housing and four rubber feet, allowing it to be placed on any hard surface up to 10 feet (3 m) away from the pump. For greater distances [up to 328 ft. (100 m)], additional pump cable with connectors must be ordered.

For mounting the converter in a standard 19-inch rack, an Installation Frame (Part No. 16100) and a Front Panel with Cutout (Part No. 16101) should be used. See Fig. 3-2.

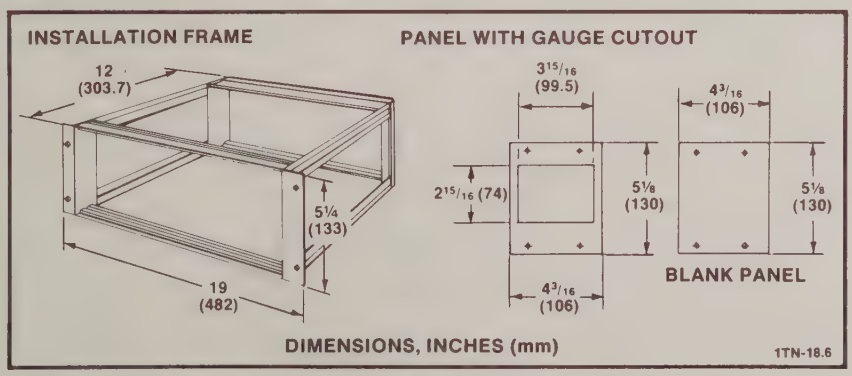


Figure 3-2. 19-Inch Rack Installation Frame with Cutout and Blank Front Panels

For mounting the converter onto a panel of up to 1/8 inch (3 mm) in thickness, a 2-15/16 X 3-15/16 inch, right-angle hole must be cut out in the panel. Refer to Table IV Dimensional Data at the front of this manual.

The converter is mounted onto a panel by clamping the panel between the converter's front cover and housing as follows:

1. Remove the converter from its housing (refer to Section 5.5 NT-50 Disassembly).

2. Push the power cable and converter through the front of the panel cutout, until the rear of the converter's front cover lies on top of the panel.

3. From the back of the panel, reinstall the converter housing and secure in place using the screws and metal spacers which were removed in step 1. Ensure that the panel fits tightly between the converter's front cover and housing.

3.3.4 CONVERTER REAR PANEL TERMINAL BLOCK WIRING

Figure 3-3 illustrates the converter's rear panel wiring. Additional wiring information in contained in Sections 3.3.4.1 thru 3.3.4.3.

3.3.4.1 Initial Wiring

If you DO NOT wish to use the remote start-stop features, connect a jumper to rear panel STOP terminals 2 and 3. See Fig. 3-3(a).

3.3.4.2 Remote Start/Stop Wiring

Rear panel STOP and START terminals 1, 2, and 3 are inputs to be used for starting and stopping the pump from a remote location. The following are two methods for wiring the converter for remote starting and stopping:

1. The first method uses two momentary pushbutton switches which function the same way as the converter's front panel START/STOP controls. This wiring arrangement uses a momentary switch closure to start the pump, and a momentary switch open to stop the pump. Note that a short term power failure will stop the pump, requiring the pump to be manually restarted. Wire according to Fig. 3-3(b).

2. The second method uses a single toggle switch. With this wiring configuration, the pump will start when the switch is closed, and will stop when the switch is open. An advantage of wiring your system in this fashion is that following a short term power failure, the pump will automatically restart without operator involvement. Wire according to Fig. 3-3(c).

3.3.4.3 Remote Normal Operation Sensing

Rear panel NORM OPERATION terminals 4, 5, and 6 are connected to the normally-open and normally-closed contacts of a relay which is energized when the converter switches to normal operation. External indicating or control devices can be activated by these relay contacts which are rated 4 A at 250 V AC, and 120 W at 30 V DC. See Fig. 3-3(d).

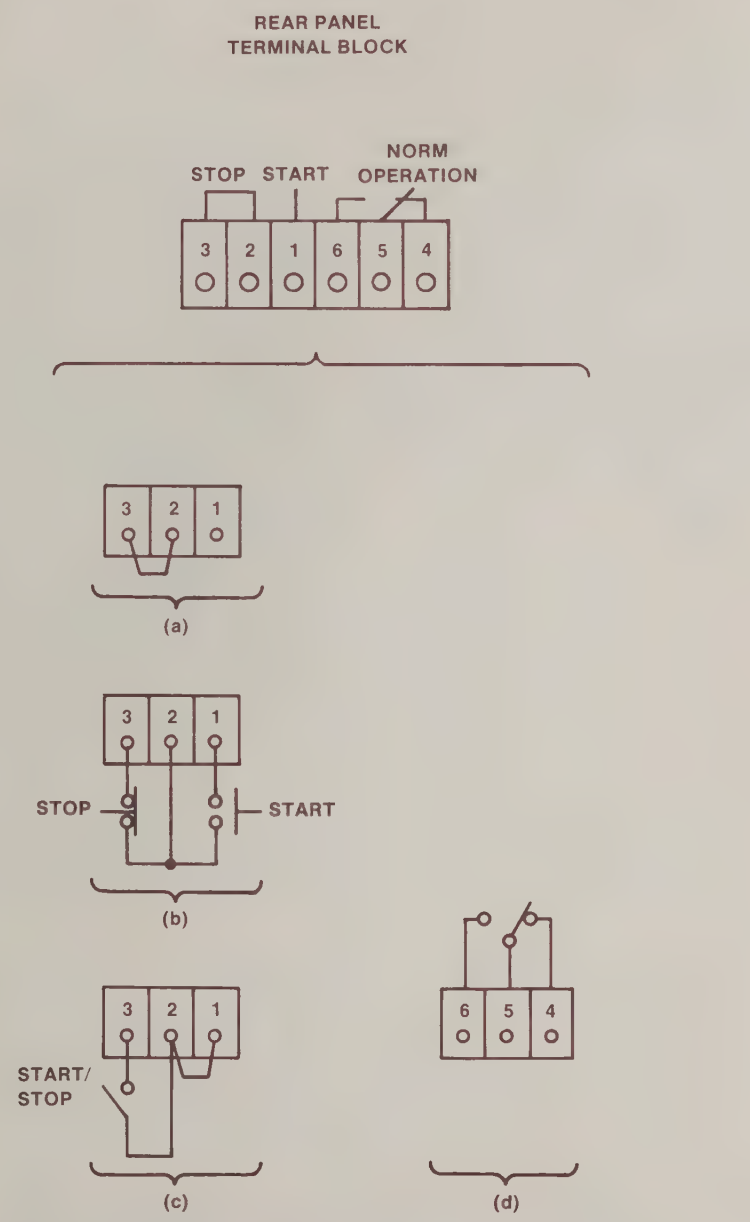
For example, a remote normal-operation lamp and its power source can be connected in series with NORM OPERATION terminals 5 and 6. Then whenever the converter switches to normal operation, these contacts will close and light the remote normal-operation lamp.

3.3.5 GROUNDING

In order to reduce the possibility of electrical shock, and to prevent a malfunction of the converter due to electrical noise, the converter should be grounded.

Use the converter's rear panel grounding stud to connect the converter chassis to either the enclosure in which it is installed, or to a nearby earth ground. Note that this ground connection is in addition to the ground wire contained in the converter's AC power cord.

Keep the inductance of the ground connection as low as practicable by using a short lead made of copper braid or heavy wire.



(a) INSTALL JUMPER WHEN REMOTE STOP/START IS NOT USED.
(b) REMOTE START/STOP USING TWO MOMENTARY PUSHBUTTONS.
(c) REMOTE START/STOP USING A SINGLE TOGGLE SWITCH.
(d) NORMAL OPERATION RELAY OUTPUTS. TERMINALS 5 AND 6 WILL CLOSE WHEN THE CONVERTER ACHIEVES NORMAL OPERATION.

1TN-18.7

Figure 3-3. NT-50 Rear Panel Wiring

3.3.6 PUMP AND CONVERTER INTERCONNECTION

The pump and converter are interconnected by a standard 10 ft. (3 m), 4-conductor pump cable which is supplied with the converter. Note that cable lengths of up to 100 ft. (30.5 m) are possible using the 4-conductor pump cable without any modifications to the converter. For cable lengths from 100 to 328 ft. (30.5 to 100 meters), however, a shielded pump cable is required. Additional pump cable with connectors can be ordered from Leybold-Heraeus.

See Fig. 3-4 and install the pump cable as follows:

WARNING

Peak voltages of between 250 and 370 volts are present in the pump cable. Therefore, route the pump cable in a manner which ensures that the cable insulation will not become nicked and thus expose these high voltages.

1. Install the Pump Connector Gasket, supplied with the converter, onto the pump's bottom electrical connector. This gasket ensures that the pump connection is dust/water proof.

2. Interconnect the pump and converter by simply screwing the pump cable's round plug onto the converter's rear panel MOTOR connector, and then pushing the cable's square plug onto the pump's bottom electrical connector.

3. Secure the pump connection by installing the Pump Connector Retaining screw, also supplied with the converter, through the center of the pump's cable plug.

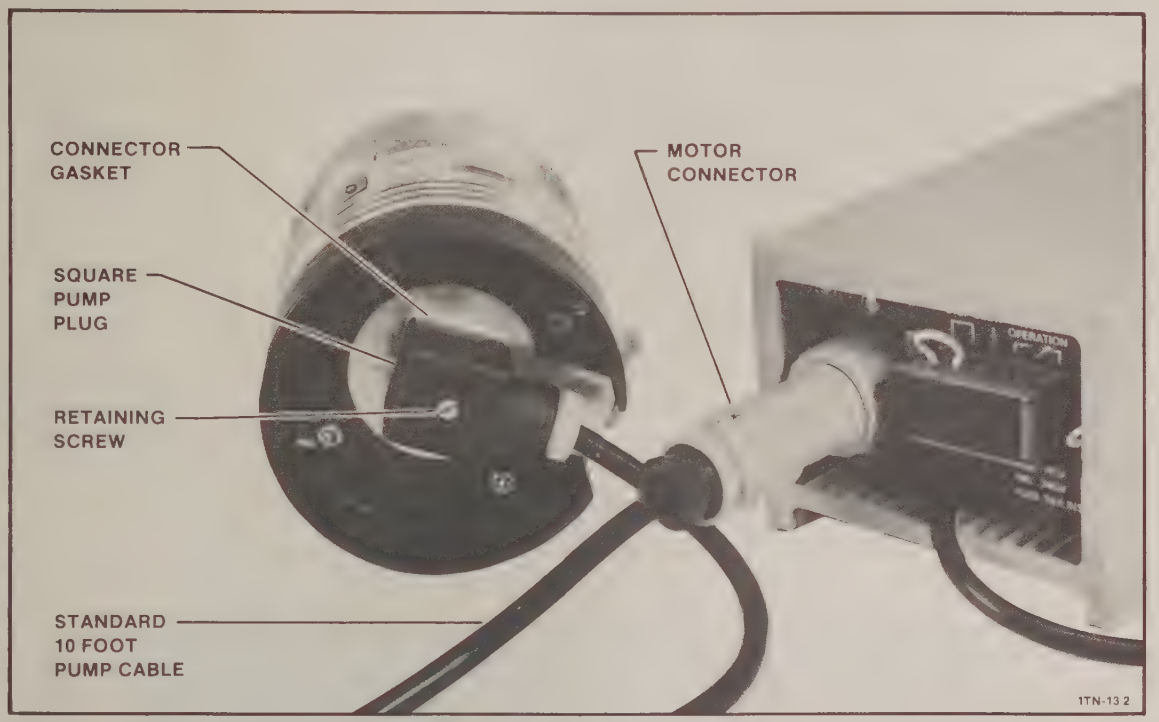


Figure 3-4. Pump and Converter Interconnection

3.3.7 CHECKING PUMP MOTOR DIRECTION OF ROTATION

Before installing the pump, check that its rotor will be turning in the correct direction when power is applied as follows:

WARNING

This equipment employs voltages which are dangerous and may be fatal if contacted. Excercise extreme caution while working with this equipment when any of its protective covers are removed. Also, to reduce the possibility electrical shock, always connect the equipment to a low impedance ground.

CAUTION

Before plugging the converter into an AC service outlet, ensure that jumper STV1 is connected for the applied AC line voltage, and that the correct fuse is installed. Refer to Section 3.3.1.

1. Install the pump cable between the pump and converter as described in Section 3.3.6.

2. Plug the converter into an AC service outlet.

3. Press the converter's POWER switch to its ON position and observe that the front panel POWER indicator should light.

4. Press START; observe rotor rotation through the turbopump's high-vacuum inlet port; then press STOP.

5. The rotor should be turning clockwise (as observed through high-vacuum inlet). The correct direction of rotation is also marked by an arrow on the motor housing. If the rotor is turning in a counterclockwise direction, proceed as follows:

   a. Unplug the converter from the AC service outlet.

   b. Remove the converter from its housing, then unlatch and fold over the top printed circuit board (refer to Section 5.5 NT-50 Disassembly).

   c. Locate connector BUV1 on the top board (Fig. 3-5). Then interchange the first two motor wires contained in this connector.

d. Repeat steps 2 thru 5 to ensure that the pump is rotating in the correct direction. Then replace the converter housing.

6. After completing this procedure, unplug the converter. If the pump is not going to be installed at this time, remove the pump cable and place the pump back into its protective shipping material and store in a dry location.

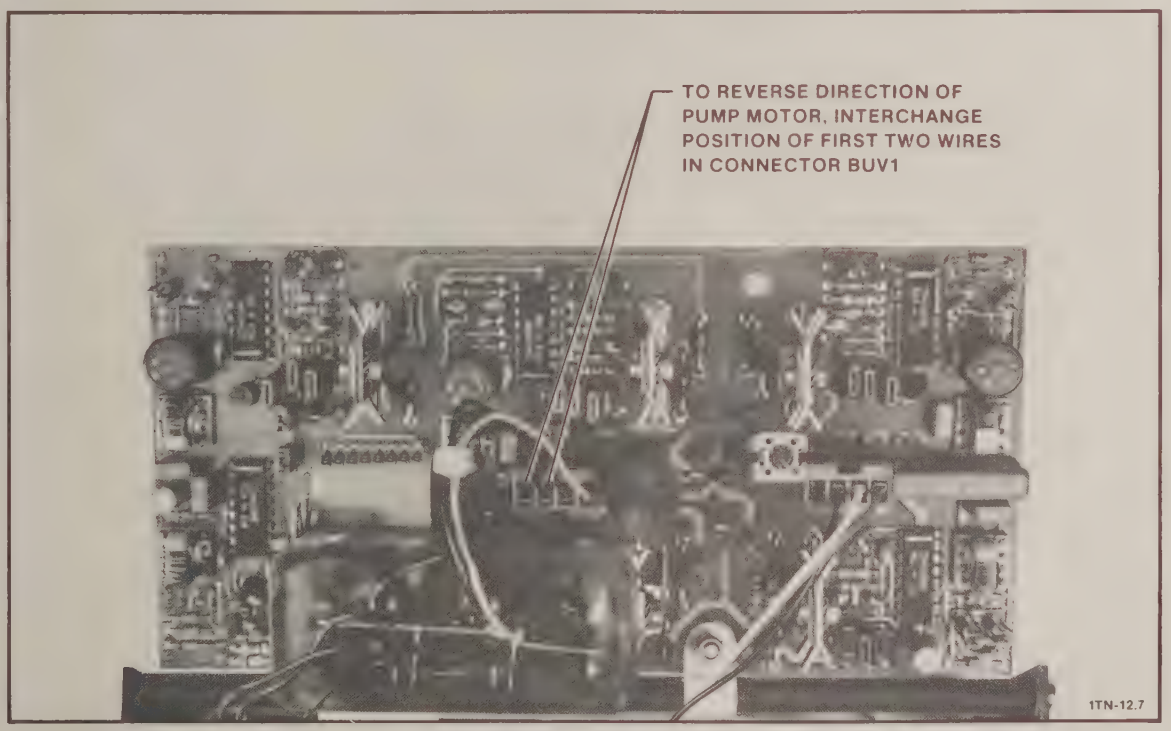


Figure 3-5. Reversing Direction of Pump Motor

3.4 TMP-50 INSTALLATION

The following procedures describe how to install the TMP-50 Turbomolecular Pump. A diagram of a typical pumping system is shown in Fig. 3-6.

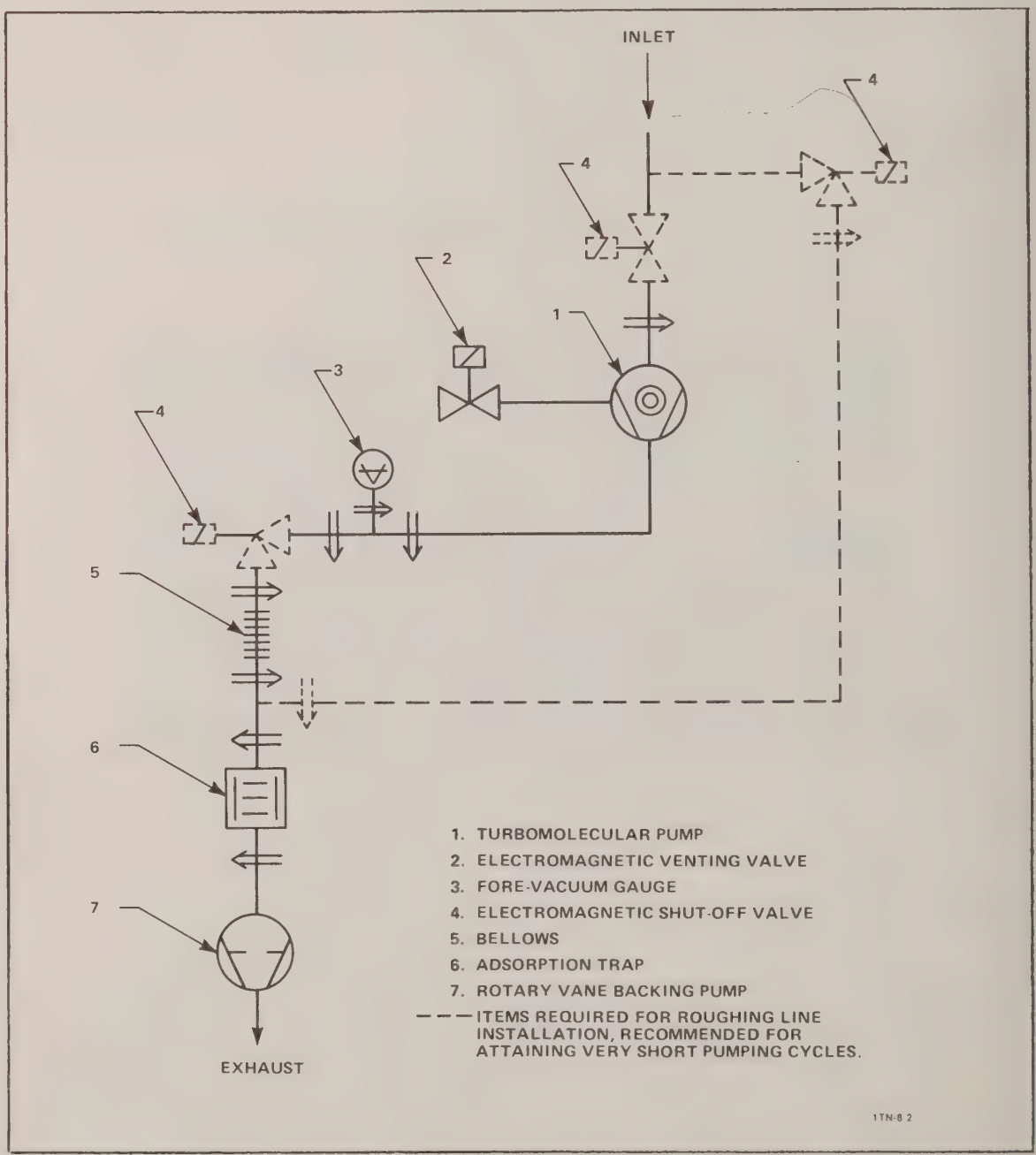


Figure 3-6. Typical Pumping System Diagram

3.4.1 INTAKE PORT CONNECTION

The pump is secured to the vacuum system using any one of the following three types of flanges: KF40, LF65, or CF63. The type of flange used depends on such factors as compatibility with other system flanges, the vacuum system's nominal operating pressure, and the maximum pumping speed required. Assembly information for the type KF and LF flanges is located in the Vacuum Fittings section of the Leybold-Heraeus Catalog ("Product and Vacuum Technology Reference Book").

Standard O-ring seals (Viton or Buna-N) are used with the KF and LF flanged pumps, but please note that the ultra-high vacuum aluminum sealing disc and clamp set CANNOT be used with these pumps because of their aluminum housing. The CF flanged pumps have stainless steel housings and use metal seals for ultra-high vacuum applications.

In most cases the TMP-50 can be mounted directly by its intake flange to the vacuum system. And due to its grease lubricating system, the pump can be mounted and operated in any angular position.

If the pump is connected to instruments highly sensitive to vibration, or to prevent external vibrations from being transmitted to the pump, Vibration Damping Bellows should be connected between the vacuum system and pump (refer to Section 1.4.6).

The KF and LF flanged pumps are normally vented through their intake ports via the vacuum chamber; however, if this is not possible, an intermediate inlet fitting for venting is required. This fitting provides a KF10 venting port, on which an Automatic

Venting Valve can be mounted. Refer to Section 1.4.5. Note that a CF flanged pump contains an integrated venting port positioned midway between its intake and exhaust ports.

Before making the high vacuum connection, ensure that the wire-mesh inlet screen is inserted into the pump's intake port. See Fig. 5-1.

3.4.2 EXHAUST PORT CONNECTION

The pump exhaust port is supplied with a type KF16 fitting. Assembly information for this and other types of vacuum fittings is located in the Leybold-Heraeus Catalog ("Product and Vacuum Technology Reference Book").

In order to achieve fast pump down times and low operating pressures, it is essential to install an adequate backing pump at the turbopump's exhaust port. We recommend using the Leybold-Heraeus TRIVAC D1.6B or D2A Rotary Vane Pump as the backing pump.

To prevent backstreaming of oil from the backing pump toward the TMP-50 either upon shut-down or in the event of a power failure, a TRIVAC pump incorporates an internal anti-suckback device which automatically closes the fore-vacuum line when the backing pump is switched off. If another type of backing pump is used, an airing/isolating valve that seals off the backing pump's intake port should be installed. We recommend using the Leybold-Heraeus SECUVAC® valve (KF reducer fittings may also be required).

To ensure that the fore-vacuum space of the TMP-50 remains free from oil vapors, an adsorption trap should be installed into the fore-vacuum line. Consult Leybold-Heraeus for the type of trap best suited to your particular application.

When pumping down large chambers, the chamber should be roughed down with the backing pump before starting the turbopump. In this situation, a separate roughing line is installed between the chamber and backing pump. Roughing the chamber in this manner will decrease the roughing time, and also prevent the backstreaming of oil vapors from the backing pump up through the turbopump while it is at a standstill.

To prevent vibrations from being transmitted from the backing pump to the TMP-50, use bellows or flexible tubing to connect these two pumps.

3.4.3 TURBOPUMP COOLING

Cooling of the TMP-50 is not required under most operating conditions. The maximum ambient temperature for a non-baked pump in continuous operation at operating pressures below 10^{-4} mbar is 122°F (50°C).

In cases of extreme thermal load, such as ambient temperatures higher than 122°F (50°C), continuous operation at high pressure on the high-vacuum side, or rapid cycle operation, the Air Cooling or Water Cooling Unit (refer to Sections 1.4.2 and 1.4.3) should be installed as described in Sections 3.4.3.1 and 3.4.3.2.

The maximum ambient temperature for a CF flanged pump that is being air-cooled and continuously baked out is 104°F (40°C). At higher ambient temperatures, the Water Cooling Unit should be installed as described in Section 3.4.3.2.

3.4.3.1 Air Cooling Unit Installation

The Air Cooling Unit is installed between the pump's motor housing and bottom support as follows (see Fig. 3-7):

Using a 3-mm Allen wrench, remove the four screws that secure the pump-support base to the motor housing. Then mount and secure the Air Cooling Unit between these two items using the original four screws.

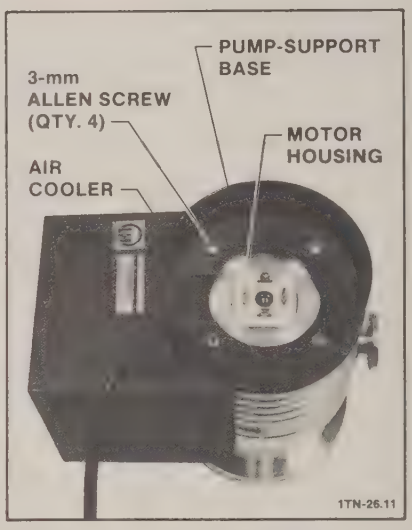


Figure 3-7. Air Cooling Unit Installation

When installing the pump, ensure that the Air Cooling Unit's air inlet is not obstructed.

Connect the Air Cooling Unit's power cord through an electrical switch to a source of either 115 or 220 VAC (depending on model ordered), single-phase power. The Air Cooling Unit will consume approximately 12 watts of power. Locate the electrical switch near the converter so that the Air Cooling Unit can be switched on and off simultaneously with the pump.

3.4.3.2 Water Cooling Unit Installation

The Water Cooling Unit is installed at the bottom of the pump's motor housing as follows (see Fig. 3-8):

Using a 3-mm Allen wrench, remove the four screws that secure the pump-support base to the motor housing. Then mount and secure the Water Cooling Unit to the motor housing using the four M3x2.5 mm Allen screws and washers which were supplied with the Water Cooler. The old pump-support base and screws

should be saved if you should later decide to remove the water cooler.

Use 7/16" (11 mm) I.D. hose to connect the Water Cooling Unit through a water valve to a source of clean tap water, which is at a temperature of between 59 and 77°F (15 and 25°C) and at a pressure of between 40 and 90 psig. Use hose clamps to secure the hoses to the water cooler. Locate the water valve next to the converter so that the cooling-water flow can be turned on and off simultaneously with the pump.

Figure 3-8. Water Cooling Unit Installation

To ensure that clean water is being fed through the Water Cooling Unit, install a fine-mesh strainer or automotive fuel filter into the cooling water supply line.

3.4.4 AUTOMATIC VENTING VALVE INSTALLATION

The TMP-50 should be vented to atmospheric pressure immediately when switched off. Venting prevents back-diffusion of the process gas and/or oil vapors from the fore-vacuum line into the high-vacuum side of the turbopump. Venting is normally accomplished through the vacuum chamber for KF and LF flanged pumps, and through the integrated venting port of a CF flanged pump.

Venting gas should enter the pumping system through an Automatic Venting Valve (refer to Section 1.4.4) which mounts on a KF10 flange.

If venting from the vacuum chamber is not possible, the KF and LF flanged pumps require the installation of an Intermediate Venting Flange (refer to Section 1.4.5) on their high-vacuum inlet. This intermediate flange provides a KF10 port on which the venting valve can be mounted. See Fig. 3-9.

Either leave the input side of the Automatic Venting Valve open to the atmosphere, or preferably, connect it to a bottled source of venting gas (i.e., dry nitrogen) using whatever fittings are necessary. DO NOT exceed a venting pressure of 7 psig when using a pressurized venting line.

Connect the Venting Valve through an electrical switch to a source of 115 V AC, single-phase power. Locate the switch near the converter so that the pump can be immediately vented after being shut off.

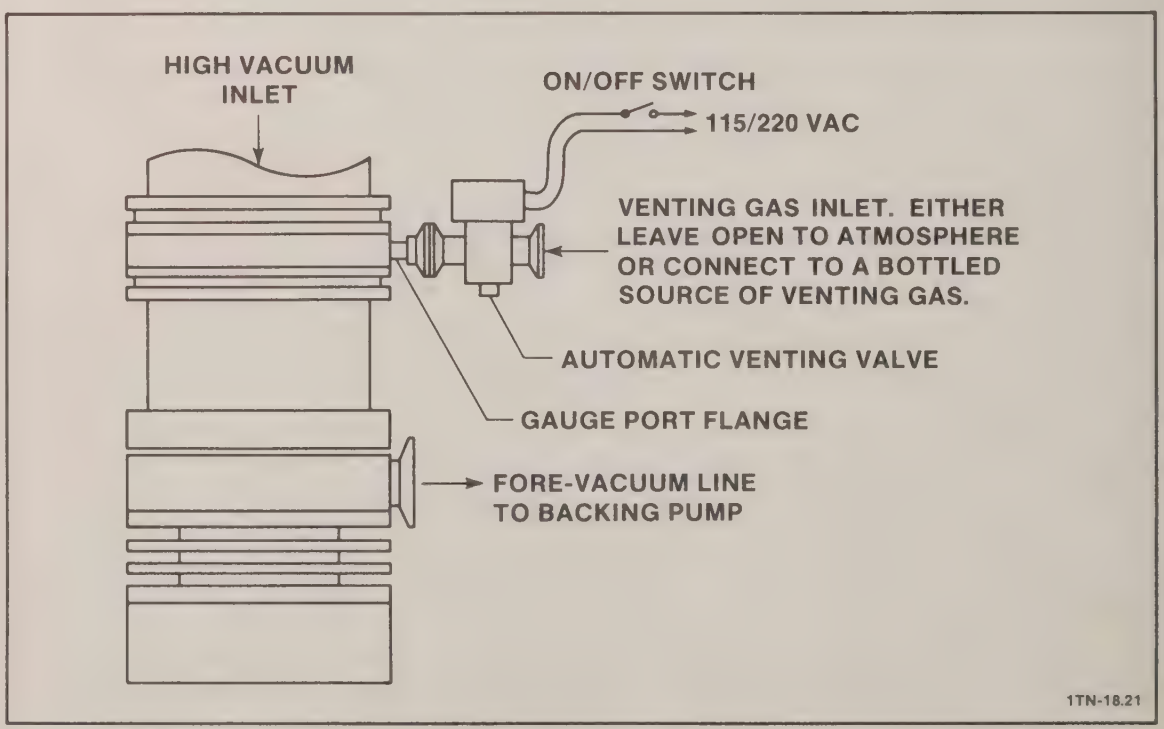

HIGH VACUUM INLET
ON/OFF SWITCH
115/220 VAC
VENTING GAS INLET. EITHER LEAVE OPEN TO ATMOSPHERE OR CONNECT TO A BOTTLED SOURCE OF VENTING GAS.
AUTOMATIC VENTING VALVE
GAUGE PORT FLANGE
FORE-VACUUM LINE TO BACKING PUMP
1TN-18.21

Figure 3-9. Automatic Venting Valve mounted to an LF65 TMP50 using a Gauge Port Flange

3.4.5 BAKEOUT JACKET INSTALLATION

The Bakeout Jacket is used only on CF flanged pumps when operating pressures of $<10^{-7}$ mbar are required (refer to Section 1.4.1).

See Fig. 3-10. Position the Bakeout Jacket around the pump's CF63 intake flange and secure in place by tightening its clamp screw using a 4-mm Allen wrench.

Figure 3-10. Bakeout Jacket Installation

Connect the Bakeout Jacket's power cord through an electrical switch to a source of either 115 or 220 VAC (depending on model ordered), single-phase power. The Bakeout Jacket will consume approximately 100 watts of power.

NOTES

SECTION 4
OPERATION

4.1 GENERAL INFORMATION

This section contains information on how to start, operate, and stop the TMP/NT-50 vacuum pumping system. Information on turbopump venting and bakeout is also presented.

4.2 NT-50 FRONT PANEL CONTROLS AND INDICATORS

The following functions are performed by the NT-50 Frequency Converter's front panel controls and indicators, see Fig. 4-1:

PUSHBUTTON CONTROLS:

POWER ON/OFF - Turns frequency converter ON/OFF.

START - Starts the pump. Note that it will take approximately 3 seconds after the converter is turned on or after the pump was stopped before the pump can be started.

STOP - Stops the pump or turns off the FAIL indicator.

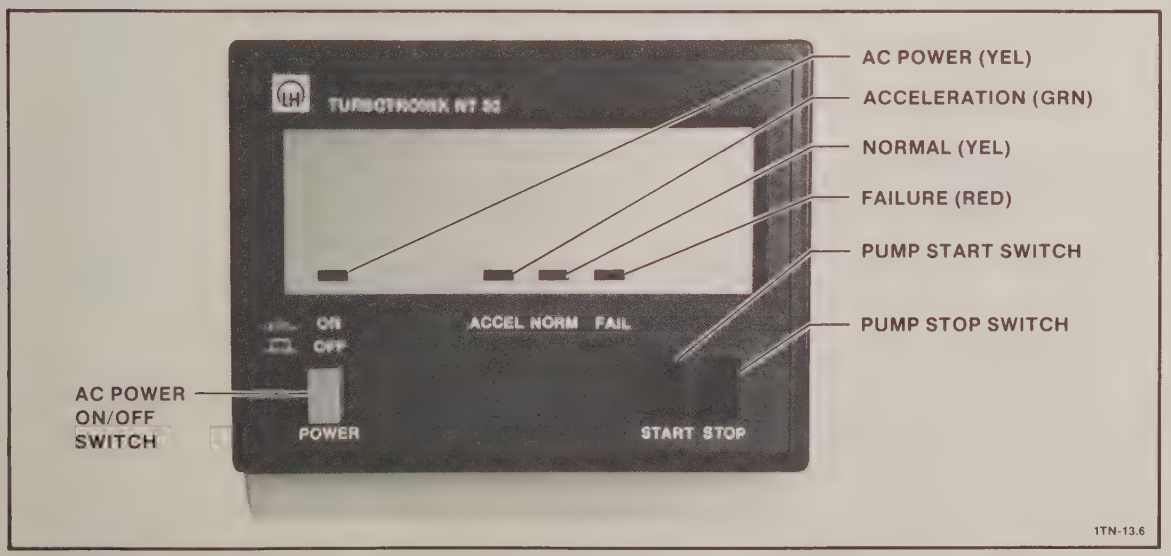


Figure 4-1. NT-50 Front Panel Controls and Indicators

INDICATORS:

POWER (Yellow) - Lights when AC power is applied to the converter.

ACCEL (Green) - Lights when the pump is accelerating. If this indicator relights after the converter achieved normal operation, this signals that the pump has been slowed down below 30% of its rated rotational speed.

NORM (Yellow) - Lights as soon as the converter reaches its maximum drive frequency. Once the NORM indicator turns on, it will remain on even if the pump becomes loaded and slows down; however, if the pump's speed drops below 30% of its rated rotational speed, the NORM indicator is turned off and the ACCEL indicator is turned back on.

FAIL (Red) - Lights when the pump has been stopped due to a thermal overload. This indicator is turned off by pressing the STOP button. If the FAIL indicator does not turn off when the STOP button is pressed, the pump is probably still too hot to be restarted. Note that the FAIL indicator will also light if the START button is pressed without the pump being connected to the converter. It will take approximately 3 minutes for the converter to recover from this condition before the FAIL indicator can be turned off by pressing the STOP button.

4.3 STARTING

To start the TMP/NT-50 vacuum pumping system, proceed as follows:

1. Before start-up, ensure that the NT-50 and TMP-50 have been correctly installed as described in Sections 3.3 and 3.4.

2. Plug the converter into an AC service outlet.

3. Press the converter's POWER ON/OFF pushbutton and observe that the POWER indicator should light.

4. Ensure that the turbopump's venting valve is closed.

5. Start the backing pump and then press the converter's START pushbutton. Observe that the converter's ACCEL indicator should light. (The turbopump can also be remotely started. Refer to Section 3.3.4.2.)

> NOTE: When pumping out small chambers (i.e., where a pressure below 1 mbar is attained within 10 minutes) the backing pump and turbopump can be switched on at the same time. Larger chambers, however, must first be roughed down by the backing pump before the turbopump is switched on; otherwise, the turbopump may overheat and be shut-down by its converter. Roughing can be accomplished either through the turbopump while it is at a standstill, or through a separate roughing line. If you rough down the chamber through the turbopump, however, an adsorption trap should be installed in the foreline to prevent the backstreaming of oil vapors up through the turbopump while it is at a standstill.

6. If used, start the optional Air Cooling or Water Cooling Unit.

7. If operational pressures of $<10^{-7}$ mbar are required, bakeout the pump as described in Section 4.7.

8. As soon as the converter reaches its maximum drive frequency, the NORM indicator will light and the ACCEL indicator will turn off. (Remote normal operation sensing is possible by using the normal-operation relay outputs at the rear of the converter. Refer to Section 3.3.4.3.)

4.4 OPERATION

4.4.1 PRECAUTIONS

Small foreign objects which may get into the pump through its intake are likely to cause heavy damage to the rotor. The pump should NEVER be operated without its supplied wire-mesh inlet screen where most of the foreign objects are trapped. Any damages that result from objects entering the rotor region are excluded from warranty.

Sudden changes of position, heavy external vibration, or blows during pump operation can be tolerated to a certain degree, but should be avoided.

During operation, DO NOT try to pump dust, highly corrosive gases at high pressure, oxidizers, or higher than atmospheric concentrations of oxygen.

4.4.2 OVERLOADS

If the turbopump is overloaded and slows down below 30% of its rated rotational speed, the converter's NORM indicator will turn off and its ACCEL indicator will turn back on. During this time, the converter applies the maximum allowable voltage to the pump motor, until the pump either reachieves normal operational speed, or is shut down because of a thermal overload.

4.4.3 POWER FAILURE

When power is restored after a power failure, the converter will come back on in its pump off state. The pump must then restarted by pressing the converter's START pushbutton. Note that the pump

can be restarted even while its is still rotating. (Automatic restart is possible by connecting an external start switch at the rear of the converter as described in Section 3.3.4.2.)

4.4.4 OVERTEMPERATURE

If the pump becomes too hot, the converter will stop the pump and light the FAIL indicator.

An overtemperature condition can be the result of high pressure at the pump's high-vacuum inlet. Under these conditions, the NT-50 will try, using maximum permissible motor voltage, to maintain or reattain the pump's rated rotational speed, until the pump's maximum allowable temperature is exceeded.

To restart the pump: 1) allow the pump to cool, 2) press the converter's STOP button to turn off the FAIL indicator, 3) press the START button to restart the pump.

> NOTE: If the FAIL indicator does not turn off after pressing STOP, the pump is still too hot to be restarted.

4.4.5 RESTARTING AFTER AN INTERRUPTION OF OPERATION

If the pump is interrupted during operation as the result of either pressing the STOP button or a power failure, the pump can be restarted at any rotational speed by pressing the START button. After such an interruption, note that the START button is not functional for approximately 3 seconds.

4.5 STOPPING

Stop the TMP/NT-50 vacuum pumping system as follows:

1. Stop the turbopump by pressing the converter's STOP pushbutton.

2. If an Air Cooling or Water Cooling Unit is used, turn off this unit immediately after stopping the turbopump to avoid condensation of vapors within the pump.

3. Switch off the TRIVAC backing pump. Its anti-suckback device should automatically close the fore-vacuum line to prevent backstreaming of oil vapor into the turbopump. If another type of backing pump is used, close the external airing/isolation valve before switching off the backing pump (note that if a Leybold-Heraeus SECUVAC valve is installed in the fore-vacuum line, this valve will automatically close when the backing pump is switched off).

4. Vent the turbopump through its venting valve with dry air or nitrogen while the turbopump's rotor is still rapidly rotating. This procedure prevents the backstreaming of the process gas and/or oil vapors from the fore-vacuum area into the high-vacuum side of the turbopump. For additional venting information, refer to Section 4.6.

5. If the turbopump is removed from the vacuum system after venting with dry gas, seal off its intake and exhaust ports with blank flanges. Also, when storing the turbopump for prolonged periods of time, place the pump into its PVC shipping bag with moisture adsorbent and store in a dry location.

4.6 VENTING

The turbopump should be vented during shut-down to prevent the backstreaming of the process gas and/or oil vapors from the fore-vacuum area into the turbopump's high-vacuum side.

The KF and LF flanged turbopumps are normally vented through their intake ports via the vacuum chamber by an Automatic Venting Valve; however, if this in not possible, an intermediate inlet fitting for venting is required (refer to Section 1.4.5). This fitting provides a KF10 venting port, on which a venting valve can be mounted. Note that a CF flanged pump contains an integrated venting port positioned midway between its intake and exhaust ports.

Dry air or nitrogen is recommended for venting because it will prevent condensation of water vapor in the pumping system. If a pressurized venting line is used, DO NOT exceed a vent port inlet pressure of 7 psig.

When the turbopump is vented without using the Automatic Venting Valve, it is advisable to proceed in accordance with the pressure rise graph shown in Fig. 4.2. Shock venting should be avoided, but it can be done in emergency situations without damaging the pump.

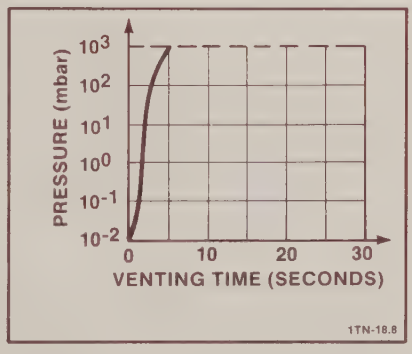


Figure 4-2. Safe High Vacuum Side Venting - Pressure Rise vs. Venting Time

4.7 BAKEOUT (CF FLANGE ONLY)

For attaining operating pressures down to 10^{-7} mbar, generally the turbopump does not need to be baked.

In order to attain operational pressures of $<10^{-7}$ mbar, both the vacuum chamber and turbopump must be baked out. A CF flanged turbopump is baked out by using its Bakeout Jacket (refer to Section 1.4.1). Normally a bakeout time of 6 hours is sufficient. Longer baking times will, as a rule, not significantly improve the ultimate operational pressure.

CAUTION

Bakeout of a LF or KF flanged pump IS NOT possible because of their aluminum housings.

During bakeout of the vacuum chamber, the turbopump intake flange temperature must not exceed 176°F (80°C). Therefore, precautions must be made to protect against direct heat radiation from the vacuum chamber's heater.

When baking out components at the fore-vacuum side (e.g., adsorption trap), make sure that the temperature of turbopump's exhaust flange also does not exceed 176°F (80°C).

The turbopump can be continuously baked out while running with the addition of the optional Air Cooling Unit; however, note that the ambient air temperature for an air-cooled turbopump during bakeout must not be higher than 104°F (40°C). At higher ambient temperatures a Water Cooling Unit must be used (refer to Section 1.4.3).

SECTION 5
MAINTENANCE AND ADJUSTMENTS

5.1 GENERAL INFORMATION

This section contains information on vacuum system preventive maintenance, TMP-50 cleaning, TMP-50 disassembly/reassembly, NT-50 disassembly, and NT-50 adjustment.

Figure 5-1 shows an exploded view of the TMP-50. Refer to this figure as necessary in the following sections.

5.2 PREVENTIVE MAINTENANCE

The TMP-50 is maintenance free. This turbopump contains life-time lubricated bearings which do not require regreasing. The only time service may be required is if the pump becomes contaminated, or if its replaceable rotor/spindle assembly becomes defective.

The NT-50 is also maintenance free. This converter is an all solid-state unit which does not require any further attention once it has been adjusted for proper operation.

WARNING

Poisonous or explosive gas can collect in filters and traps when pumping hazardous process gases. Use proper precautions to protect personnel when maintaining filters and traps.

Filters and Traps mounted in the vacuum and fore-vacuum lines must be maintained to be effective. A filter element that is saturated with contaminants can not protect your vacuum system. A dirty inlet filter or foreline trap also has poor conductance which

reduces the pumping speed. A dirty exhaust filter on the backing pump results in backpressure which reduces pumping speed and makes it difficult to maintain the required pressure in the system. Backpressure can also result in damage to the backing pump. It is therefore essential that you set up a maintenance schedule which keeps the system's filters and traps clean. The frequency of maintenance depends on the contaminant load generated by your process.

5.3 TMP-50 CLEANING

Slight contamination (e.g., by an oil film) can be cleaned without disassembling the turbopump. In case of heavy contamination, however, it will be necessary to first disassemble the pump as described in Section 5.4, and then apply cleaning solvent to the rotor blades, stator rings, and stator disk halves using a brush.

WARNING

If the pump has been exposed to toxic gases, the pump could be contaminated with dangerous chemicals. In such cases, use the proper precautions to prevent inhaling or coming in contact with these chemicals when disassembling the pump.

CAUTION

DO NOT apply cleaning solvent to any of the O-rings. Some solvents will dissolve or cause swelling and cracking of the O-ring material. Also, DO NOT allow the cleaning solvent to enter the spindle assembly which contains the greased ball bearnings.

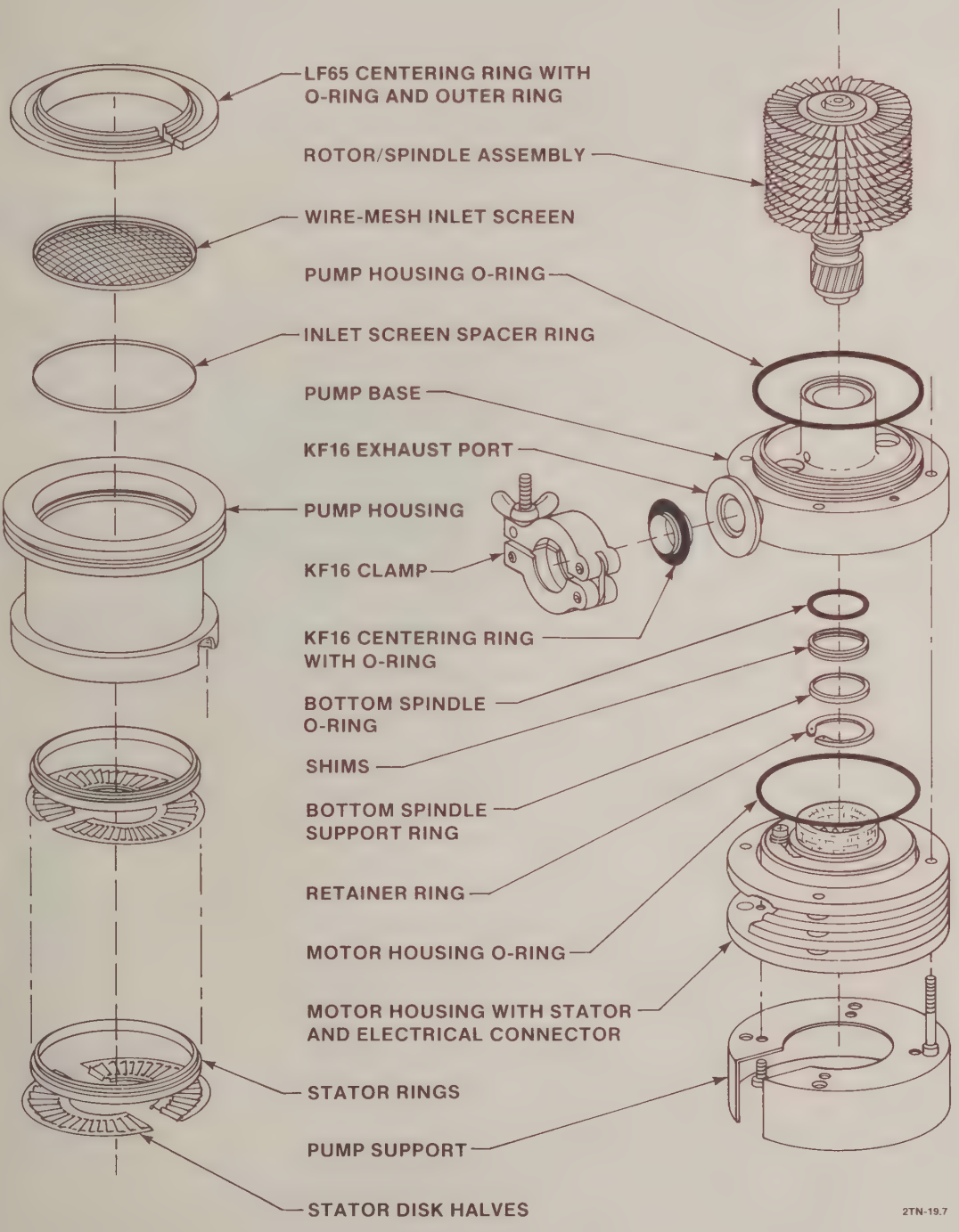


Figure 5-1. TMP-50 Exploded View

To clean the pump without disassembly, proceed as follows:

1. Prepare a clean work area, and obtain a container suitable for soaking the turbopump in a cleaning solvent such as Trichlorethylene, Acetone, or Freon. See Fig. 5-2.

2. Remove all connections from the turbopump and place in the clean work area.

CAUTION

In the following step, DO NOT allow the cleaning solvent level to be higher than 5/8 inch (15 mm) below the lower edge of the fore-vacuum connection flange, see Fig. 5-2. This prevents cleaning solvent from entering into the greased ball bearing assembly.

3. Slowly lower the turbopump upside down into a container filled with cleaning solvent. See Fig. 5-2.

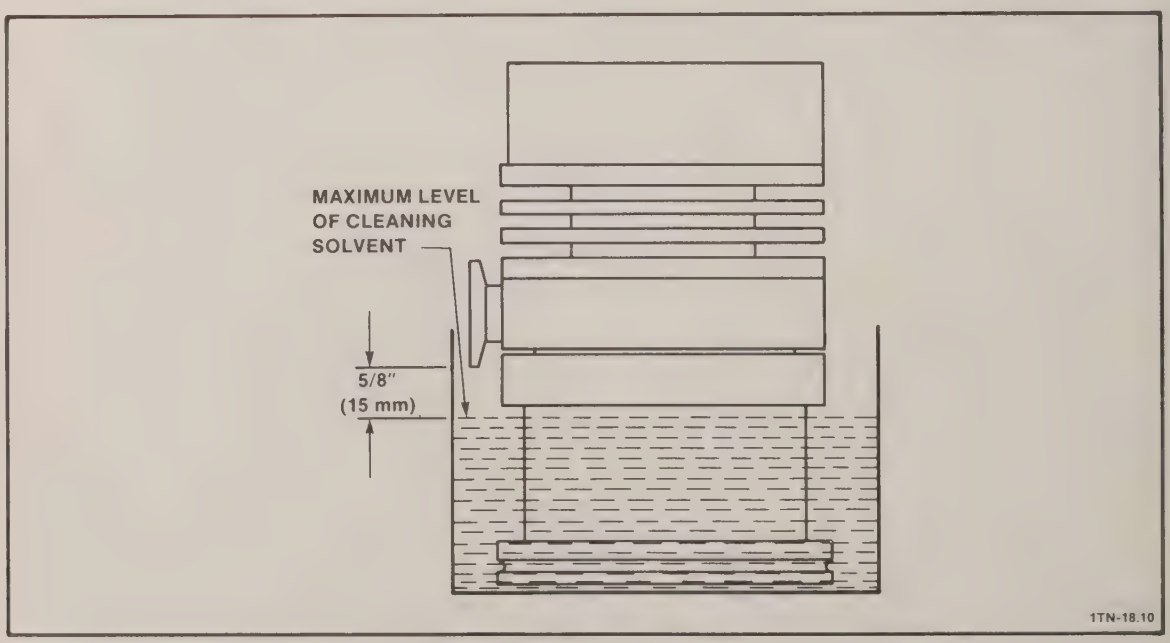


Figure 5-2. TMP-50 Cleaning without Disassembly

4. Allow the cleaning solvent to react for about 15 minutes. During this period, GENTLY lift and lower the turbopump several times to flush the rotor and stator components.

5. Repeat steps 3 and 4 at least once using fresh solvent.

CAUTION

After cleaning, DO NOT turn the pump right-side up until all cleaning solvent has been removed as described in step 6. This prevents cleaning solvent from entering into the greased ball bearing assembly.

6. After cleaning, place the turbopump, with its high-vacuum port facing down, on a piece of cardboard for at least 2 hours to allow the solvent to drain and completely evaporate. During this period, place the turbopump for a short time on its side, and roll it around its axis to allow the solvent to drain from between the stator package and pump housing.

7. When the turbopump is completely dry, remount the pump onto your system.

5.4 TMP-50 DISASSEMBLY/REASSEMBLY

WARNING

If the pump has been exposed to toxic gases, the pump could be contaminated with dangerous chemicals. In such cases, use the proper precautions to prevent inhaling or coming in contact with these chemicals when disassembling the pump.

The TMP-50 should only need to be completely disassembled if it is heavily contaminated and requires cleaning, or if a defective rotor/spindle assembly needs to be replaced.

The following sections describe how to disassemble and then reassemble the TMP-50. Please read all of these instructions before starting to disassemble the pump.

5.4.1 TOOLS AND MATERIALS REQUIRED

The following tools and materials are required to disassemble/reassemble the TMP-50:

- o 3-mm Allen Wrench
- o 1/4 inch Flat Blade Screwdriver
- o Needle Nose Pliers
- o Snap Ring Pliers
- o Feeler Gauges 0.1 to 0.3 mm (0.005 to 0.010 in.)
- o M4 x 30-mm Screw (Qty. 2)

5.4.2 TURBOPUMP DISMOUNTING AND WIRE-MESH INLET SCREEN REMOVAL

This procedure dismounts the turbopump and removes its wire-mesh inlet screen.

1. Prepare a clean work area. Use a plastic or rubber pad as a support for the turbopump.

2. Remove all connections from the turbopump (i.e., converter cable, inlet and exhaust port connections).

3. Remove the turbopump from the vacuum system and place in the clean work area.

4. Using Needle Nose Pliers, grasp the wire-mesh inlet screen and carefully pull the screen out of the turbopump (Fig. 5-3). Also remove the inlet screen spacer ring (if used).

5. This completes the turbopump dismounting and wire-mesh inlet screen removal procedure. Proceed to Section 5.4.3 to remove the motor housing.

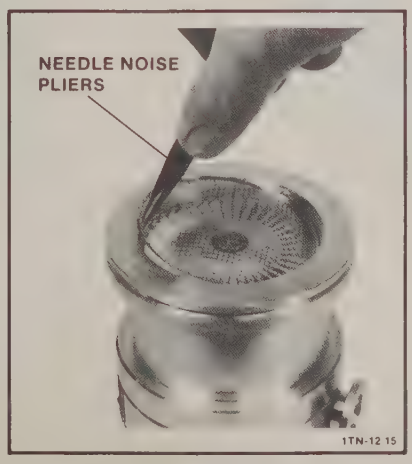


Figure 5-3. Wire-Mesh Inlet Screen Removal

5.4.3 MOTOR HOUSING REMOVAL

This procedure removes the turbopump's motor housing.

1. Place the turbopump upside down on its inlet port.

2. Using a 3-mm Allen Wrench, loosen the four pump housing screws (Fig. 5-4A). Note that these screws cannot be removed through the plastic pump support.

3. Grasp the motor housing and pull it off of the pump base (Fig. 5-4B).

4. This completes the motor housing removal procedure. Proceed to Section 5.4.4 to remove the pump housing and to disassemble the stator package.

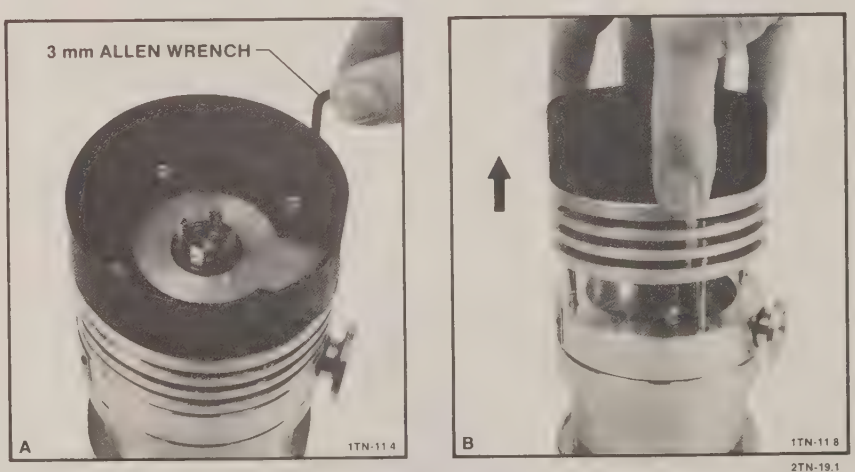


Figure 5-4. Motor Housing Removal

5.4.4 PUMP HOUSING REMOVAL AND STATOR PACKAGE DISASSEMBLY

This procedure describes how to remove the TMP-50's pump housing and then disassemble its stator package.

1. Insert two M4 x 30-mm screws into the jack screws holes of the pump base (Fig. 5-5A). Tighten these two screws uniformly until the pump housing O-ring becomes visible. Then remove these jack screws.

   NOTE: If you do not have the proper size jack screws, the pump housing and pump base in most cases can be pulled apart by hand, or CAREFULLY pried apart using a flat blade screwdriver.

2. Set the turbopump upright on top of its motor housing, and then pull off the pump housing (Fig. 5-5B).

3. Lift off the first stator ring (Fig. 5-5C) and place it upside down next to the turbopump.

4. Pull out the first two stator disk halves (Fig. 5-5D) and place them upside down in the first stator ring.

   NOTE: During disassembly of the stator package, check for damaged stator rings and stator disk halves. Look for friction marks, cold welds, and deformed parts. Repair or replace any damaged part(s) before reassembling the pump.

5. Continue to lift off the stator rings and pull out the stator disk halves, until the complete stator package is stacked upside down next to the turbopump (Fig. 5-5E).

6. This completes the pump housing removal and stator package disassembly procedure. Proceed to either Section 5.4.6 to reassemble the stator package, or to Section 5.4.5 if you want to replace the rotor/spindle assembly.

5.4.5 ROTOR/SPINDLE ASSEMBLY REPLACEMENT

The procedures contained in Sections 5.4.5.1 thru 5.4.5.4 describe how to replace the TMP-50 rotor/spindle assembly.

The following instructions assume that the turbopump been disassembled, as described in Sections 5.4.3, 5.4.2, and 5.4.4.

5.4.5.1 Rotor/Spindle Assembly Spare Parts and Accessories

The following spare parts and accessories are supplied with each new rotor/spindle assembly (P/N 200-17-187):

Qty.	Item	Part Number
10	Shim (0.1 mm)	200-17-127
1	Spindle O-Ring (22 x 2.5 mm)	200-17-134
1	Retainer Ring	200-17-132
1	Rotor Blade Clearance Gauge	200-17-258

When ready to unpack the new rotor/spindle assembly, carefully remove the assembly with its packing material from the cardboard shipping container. Save all shipping material if you intend on shipping the defective rotor/spindle assembly back to Leybold-Heraeus for servicing.

When repacking the defective rotor/spindle assembly for shipment to Leybold-Heraeus, reuse the original packing material and include one bag of moisture absorbent.

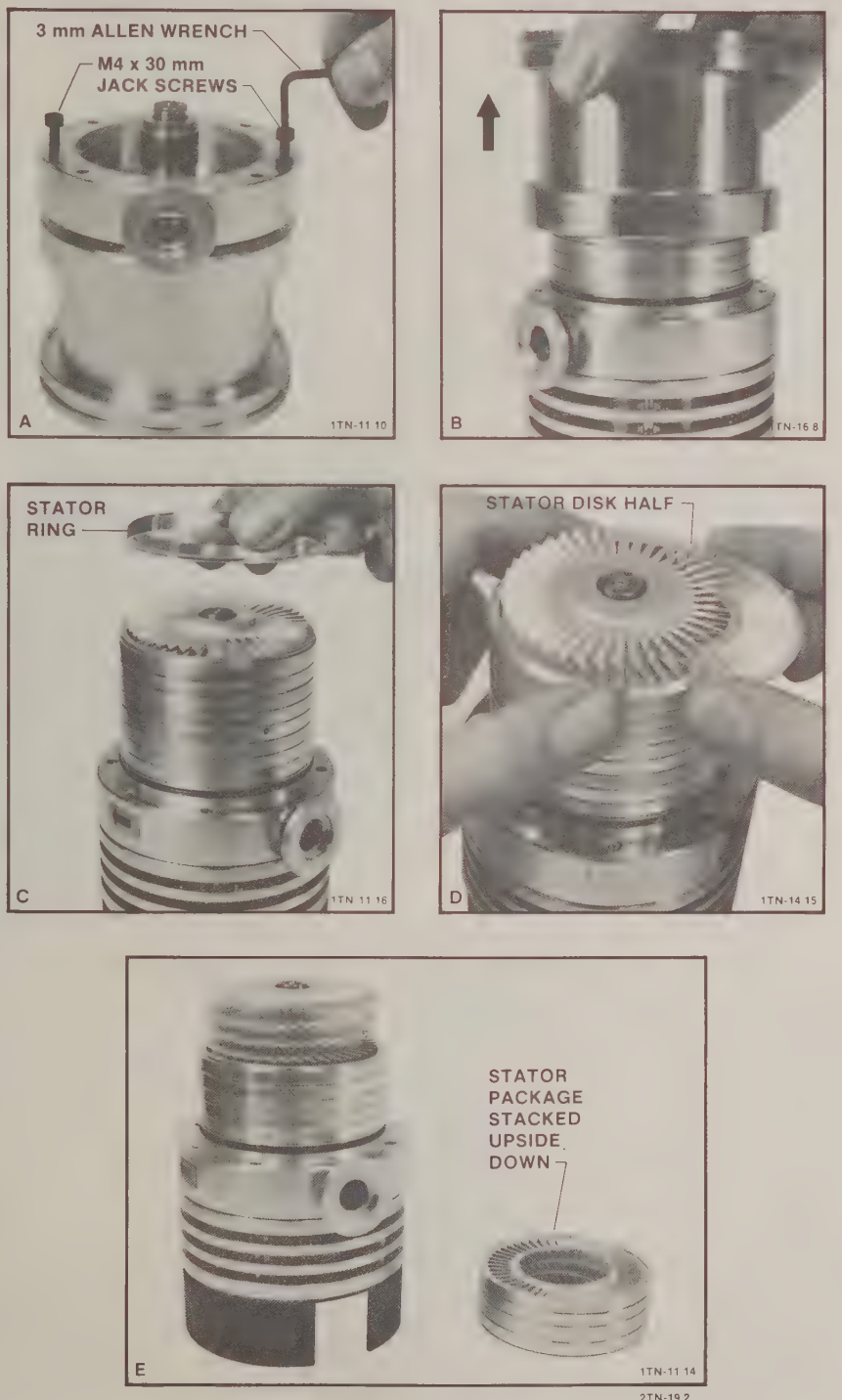


Figure 5-5. Pump Housing Removal and Stator Package Disassembly

5.4.5.2 Rotor/Spindle Assembly Removal

The following instructions describe how to remove the rotor/spindle assembly from the pump base.

1. Place the pump housing upside down on its intake flange on a piece of foam rubber. Then CAREFULLY insert the pump assembly into the pump housing (Fig. 5-6A).

2. Using snap ring pliers, remove the retainer ring located below the motor rotor (Fig. 5-6B). The rotor/spindle assembly should now fall free of the pump base.

3. Remove the bottom spindle support ring and remove any shims. (Fig. 5-6C). Count and record the number of shims that were removed. The same number of shims will be used when the new rotor/spindle assembly is installed.

4. Lift off the pump support base (Fig. 5-6D) and remove the rotor/spindle assembly from the pump housing (Fig. 5-6E).

5. This completes the rotor/spindle assembly removal procedure. Proceed to Section 5.4.5.3 to install a new rotor/spindle assembly.

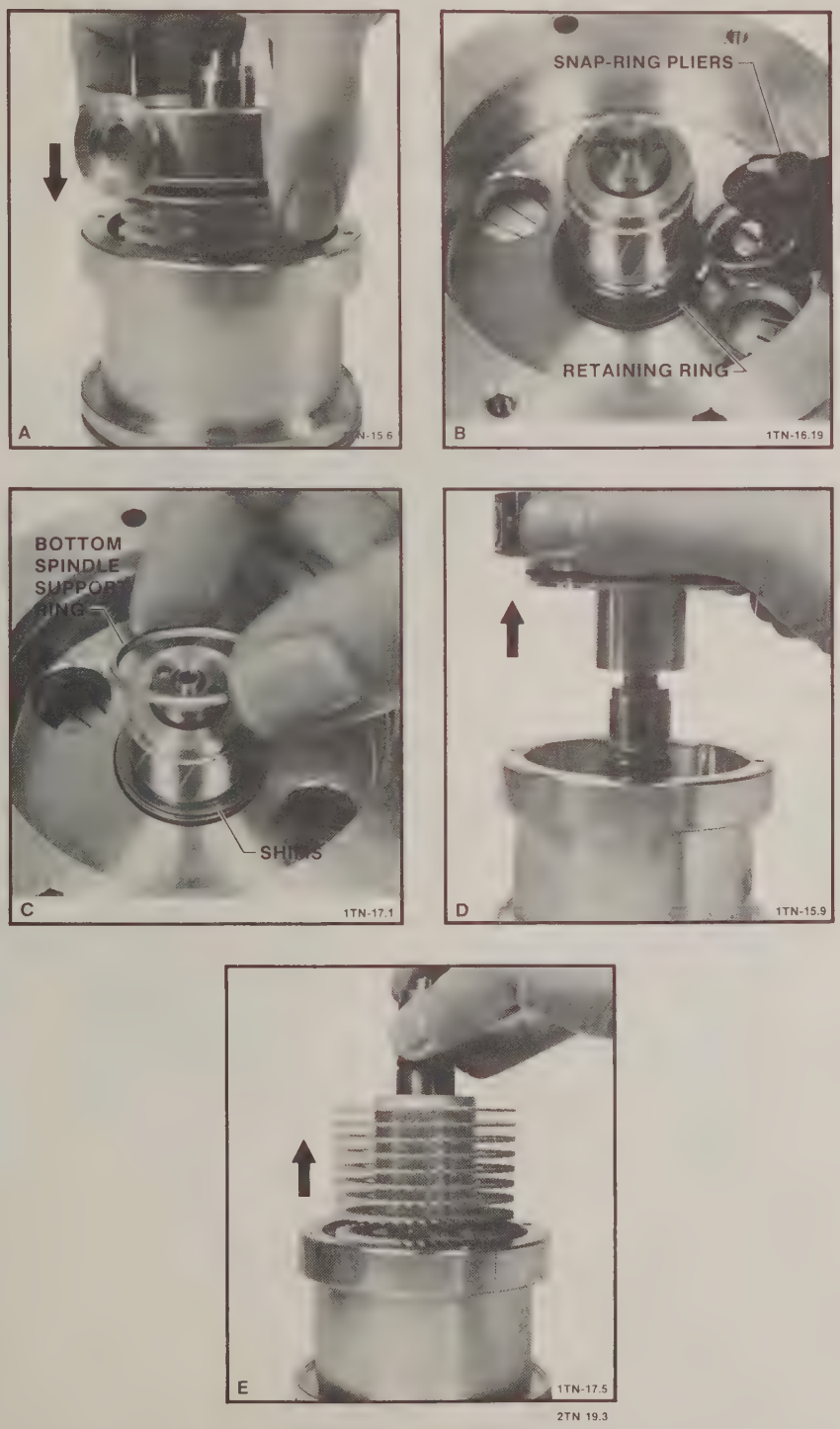


Figure 5-6. Rotor/Spindle Assembly Removal

5.4.5.3 Rotor/Spindle Assembly Installation

The following procedure describes how to install a new rotor/spindle assembly.

1. Remove all O-rings, and then clean all pump parts except the new rotor/spindle assembly with a suitable cleaning solvent (e.g., Trichlorethylene, Acetone, Freon). Let all pump parts completely dry before proceeding.

2. Make a thorough visual inspection of the pump, and replace any defective parts at this time.

3. Carefully unpack the new rotor/spindle assembly. Save all shipping material if you intend on shipping the defective rotor/spindle assembly back to Leybold-Heraeus for servicing.

4. Place the rotor/spindle assembly with its motor rotor facing upwards on a piece of foam rubber, then place the pump base over the motor rotor (Fig. 5-7A).

5. See Fig. 5-7B. Lightly coat a new spindle O-ring (supplied with the rotor/spindle assembly) with high vacuum grease, and then install the O-ring over the motor rotor. Next, install the same number of shims that were removed in Section 5.4.5.2 step 3 over the motor rotor. Then install the bottom spindle support ring over the motor rotor such that its larger flat surface is placed against the shims.

6. Using snap ring pliers, install the spindle retainer ring below the motor rotor (Fig. 5-7C).

7. Temporarily place the pump assembly into the motor housing, such that the exhaust port is located above the electrical connection opening in the pump support base (Fig. 5-7D).

8. This completes the rotor/spindle assembly installation procedure. Proceed to Section 5.4.5.4 to check the vertical alignment of the rotor blades.

Figure 5-7. Rotor/Spindle Assembly Installation

5.4.5.4 Rotor Alignment

This procedure checks the vertical alignment of the rotor blades, using the rotor-blade clearance gauge supplied with the new rotor/spindle assembly.

1. Set the rotor-blade clearance gauge on the edge of the pump base (Fig. 5-8A).

2. Using your hand, slowly turn the rotor and observe the rotor blades as they move through the teeth of the clearance gauge. The rotor blades MUST NOT touch the clearance gauge. If they do touch, proceed to step 3; otherwise, this completes the rotor alignment procedure.

3. If several blade rows touch the clearance gauge, the rotor/spindle assembly must be raised or lowered by adding or removing shims from between the bottom spindle O-ring and bottom spindle support ring (Fig. 5-8B). If, however, only single blades touch the gauge, they can be realigned using needle-nose pliers. Grip approximately one-third of the out-of-line rotor blade with pliers and realign as necessary [DO NOT move the blade more than 0.04 in. (1 mm)]. Repeat

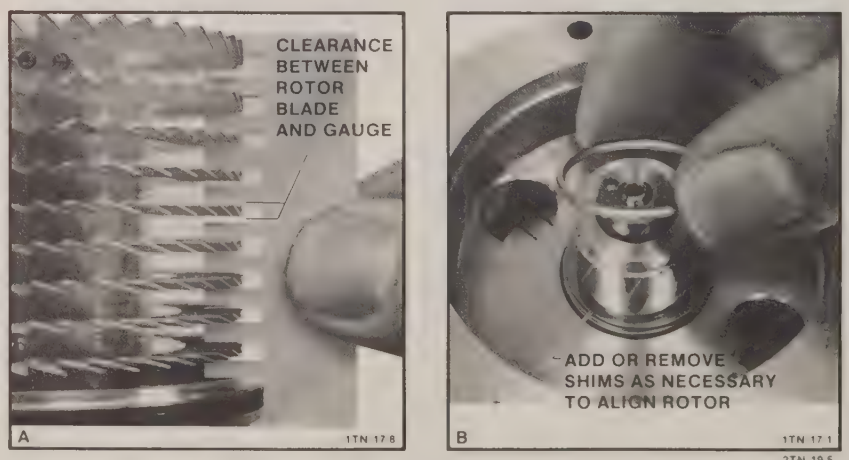


Figure 5-8. Rotor Alignment

steps 2 and 3 until all rotor blades move freely through the clearance gauge.

4. This completes the rotor alignment procedure. Proceed to Section 5.4.6 to reassemble the pump.

5.4.6 STATOR PACKAGE AND PUMP REASSEMBLY

This procedure describes how to reassemble the stator package and remaining pump parts.

Before proceeding to reassemble the pump, inspect the pump housing O-ring and the motor housing O-ring for signs of cracking or damage. Replace these O-rings (P/N 239-52-115) if necessary.

1. Apply a thin film of high-vacuum grease to the motor housing and pump housing O-rings. Then install these O-rings into the motor housing and onto the pump base.

2. Set the pump assembly into the motor housing, such that the pump's exhaust port is positioned directly above the electrical connection opening in the pump support base (Fig. 5-9A).

3. Remove the top two stator disk halves from the upside down stacked stator package, and then reinsert them below the last rotor blade row. **Be very careful to ensure that the abutting joints of the stator disk halves DO NOT overlap.**

4. Remove the top stator ring from the upside down stacked stator package and install it over the rotor. **Make sure that the gap between all the stator rings are uniform over their entire outer circumference.**

5. Using your hand, compress the stator package and alternately place stator disk halves and stator rings one above the other by repeating steps 3 and 4, until the entire stator package is reassembled onto the turbopump (Fig. 5-9B).

NOTE: It is normal that after the stator package has been installed, some blade contact and pinging will be noticable when the rotor is slowly turned. This is because the stator rings are not yet sufficiently compressed downward to form the intended clearances between the stator and rotor blades. However, after the pump housing is installed and tightened down, NO pinging should be heard.

CAUTION

To prevent the stator package from becoming dislocated, DO NOT invert or turn the turbopump on its side before the pump housing is replaced and its screws are replaced and tightened.

6. Slowly lower the pump housing directly over the stator package, being careful not to bump the stator rings which may knock them out of place (Fig. 5-9C). Ensure that the screws holes in the pump housing and pump base are in alignment. This hole alignment is essential since the pump housing O-ring prevents you from easily rotating the pump housing once it has been seated.

7. Using your hand, seat the pump housing by uniformly pressing down on the pump's intake flange. Ensure that the top of the pump housing joins properly with the top stator ring. There MUST NOT be a gap around the circumference of this joint (Fig. 5-9D).

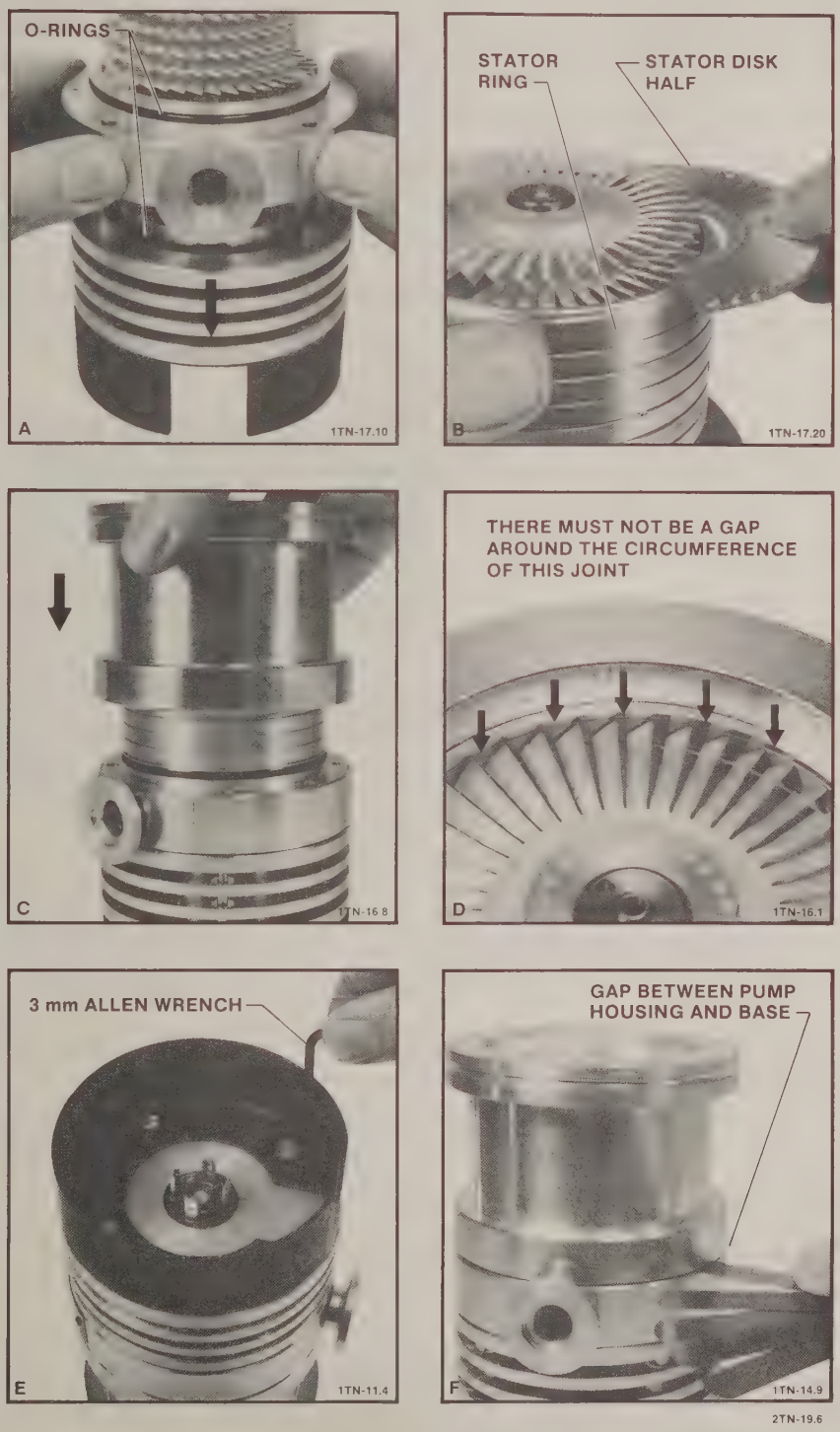


Figure 5-9. Stator Package and Pump Reassembly

8. Set the turbopump upside down on its intake flange. Then using a 3-mm Allen Wrench, uniformly cross tighten the four pump housing screws (Fig. 5-9E).

9. Using a feeler gauge, check for a gap between the pump base and pump housing (Fig. 5-9F). There MUST BE a gap of between 0.005 and 0.010 in. (0.1 and 0.3 mm), and this gap must be uniform around the circumference of the pump base. If the gap is not uniform, perform step 10; otherwise, proceed to step 11.

10. Loosen the pump housing screws and retighten them again uniformly; then repeat step 9. If still unsuccessful, remove the pump housing and check whether any stator rings have slipped off from their position or whether any stator disk halves are overlapped; then repeat steps 7, 8, and 9.

11. After installation of the pump housing, check for smooth running of the rotor by slightly pushing at the rotor hub. There should be no pinging noises and no perceptible resistance in the rotor bearings.

12. Install the inlet screen spacer ring (if used) and then the wire-mesh inlet screen.

13. This completes the stator package and pump reassembly procedure. Proceed to Section 5.4.7 to ensure that the pump has been reassembled correctly.

5.4.7 TURBOPUMP RUNNING TESTS

After reassembling the turbopump, the following Run-Up Test, Leak Test, and Venting Test procedures should be performed.

5.4.7.1 Run-Up Test

1. Install a blank flange on the high-vacuum intake port. (For CF flanged pumps, also install a blank flange on its venting port.)

2. Connect a suitable backing pump to the exhaust port.

3. Connect the turbopump to its frequency converter and start the turbopump.

4. Observe that within 5 minutes, the converter should switch from acceleration (ACCEL) to normal operation (NORM). A longer run-up time indicates improper assembly or a leak.

5. This completes the run-up test.

5.4.7.2 Leak Test

1. Install a blank flange on the high-vacuum intake port. (For CF flanged pumps, also install a blank flange on its venting port.)

2. Connect the turbopump to an ULTRATEST Leak Detector.

NOTE: If an ULTRATEST Leak Detector is not available, the working pressure of the turbopump can be measured as an indication of any leaks. A blank flanged turbopump should attain a working pressure of $<1 \times 10^{-6}$ mbar.

3. Start the leak detector and turbopump.

4. Leak check the turbopump; the leak rate should be $<1 \times 10^{-6}$ mbar ltr/sec.

5. This completes the Leak Test.

5.4.7.3 Venting Test

1. Switch off the turbopump.

2. Vent the turbopump by removing the blank flange from its intake port (for CF flanged pumps, remove the blank flange from its venting port). While detaching the blank flange, listen for any pinging noises. If no pinging noises are heard, this completes the venting test; otherwise, proceed to step 3.

3. If pinging noises are heard, you will need to disassemble the turbopump and check for proper assembly of the stator rings and stator disk halves. Also check the vertical alignment of the rotor as described in Section 5.4.5.4.

4. After reassembling the turbopump, repeat all of the running tests described under Section 5.4.7.

5.5 NT-50 DISASSEMBLY

In order to gain access to the NT-50's three printed circuit boards, remove the converter from its housing as follows:

1. Unplug the converter.

2. See Fig. 5-10A. Using a Phillips-head screwdriver, remove the housing's two upper rear-panel screws and metal spacers. Next, push against the converter's rear panel until the converter comes free of its housing, and then carefully pull the converter out of its housing.

3. See Fig. 5-10B. To expose the components on the front printed circuit board, remove the front cover's four retaining pins and then carefully pull away the front cover.

4. See Fig. 5-10C. To expose the components on the top and bottom printed circuit boards, remove the top board latch retaining screw and then fold the top board over on its hinges.

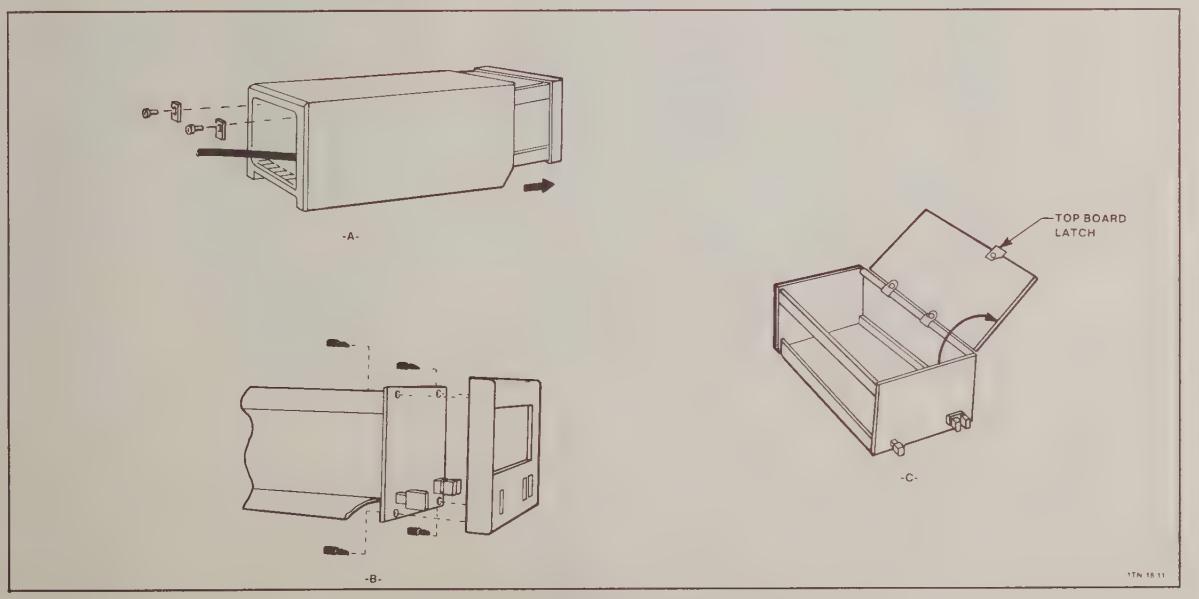


Figure 5-10. NT-50 Disassembly

5.6 NT-50 ADJUSTMENTS

This section contains information of how to adjust the five internal controls of the NT-50 shown in Fig. 5-11.

WARNING

The frequency converter employs voltages which are dangerous and may be fatal if contacted. Please note that the converter's circuit board ground is approximately 160 volts above chassis ground; therefore, exercise extreme caution when working inside the converter. Also, to reduce the possibility of electrical shock, always connect the converter's chassis to a low-impedance ground.

CAUTION

When using AC powered test equipment, float their AC line cord ground connections to prevent short circuiting the converter.

CONTROL AND STATUS INDICATION BOARD

POWER SUPPLY AND SIGNAL GENERATION BOARD

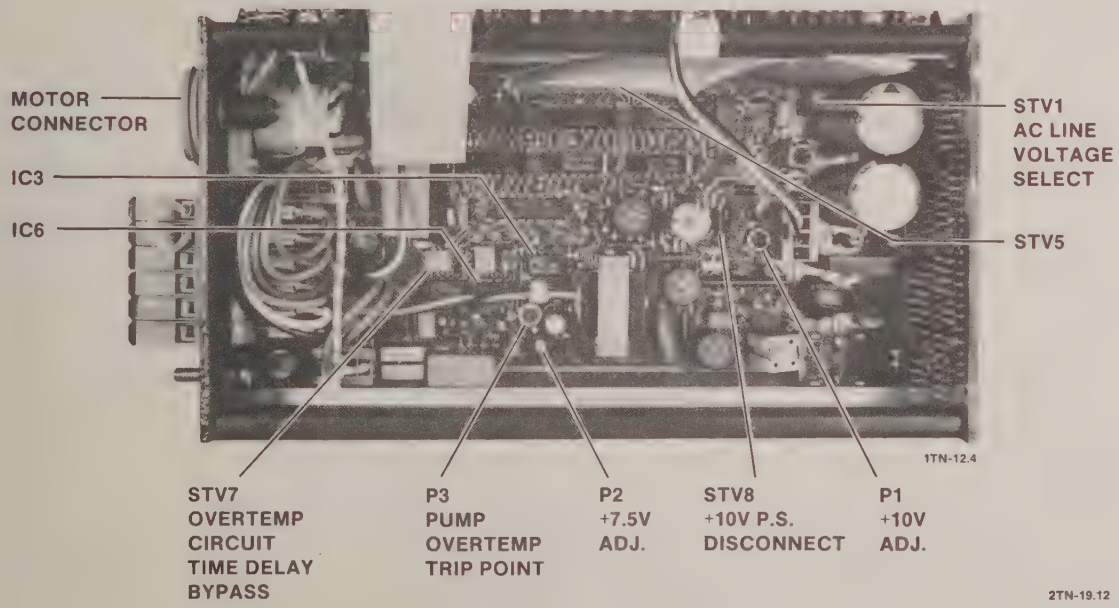


Figure 5-11. NT-50 Internal Controls

5.6.1 +10 V SWITCHING POWER SUPPLY VOLTAGE ADJUSTMENT (P1)

The +10 V Switching Power Supply Voltage control, P1, is adjusted to produce a power supply output of +10 volts. To adjust this control, see Fig. 5-11 and proceed as follows:

CAUTION

All measurements are referenced to board ground V01 which is ABOVE chassis ground. If using AC powered test equipment, float the equipment's AC ground to prevent short circuiting the converter.

1. Turn on converter by pressing its POWER pushbutton.

2. Using a voltmeter, measure the voltage on the VP1 line at connector STV5 pin 12.

3. Adjust the +10 V Switching Power Supply Voltage control, P1, for a voltmeter indication of +10 volts.

4. This completes the +10 V Switching Power Supply voltage adjustment procedure.

5.6.2 +7.5 V REFERENCE ADJUSTMENT (P2)

The +7.5 V Reference control, P2, is adjusted to produce a reference signal of +7.5 volts. To adjust this control, see Fig. 5-11 and proceed as follows:

CAUTION

All measurements are referenced to board ground V01 which is ABOVE chassis ground. If using AC powered test equipment, float the equipment's AC ground to prevent short circuiting the converter.

1. Turn on converter by pressing its POWER pushbutton.

2. Using a voltmeter, measure the voltage on the VREF line at connector STV5 pin 7.

3. Adjust the +7.5 V Reference control, P2, for a voltmeter indication of +7.5 volts.

4. This completes the +7.5 V reference adjustment procedure.

5.6.3 PUMP OVERTEMPERATURE TRIP POINT ADJUSTMENT (P3)

The motor winding temperature at which the converter turns off the turbopump is set by the Pump Overtemperature Trip Point control, P3. To adjust this control, see Fig. 5-11 and proceed as follows:

CAUTION

All measurements are referenced to board ground VO1 which is ABOVE chassis ground. If using AC powered test equipment, float the equipment's AC ground to prevent short circuiting the converter.

1. Disconnect pump cable from converter.

2. Connect a 41.5 ohm, 2 W resistor to pins 1 and 3 of the converter's rear panel MOTOR connector (these pins correspond to output lines L1 and L3).

3. Remove jumper STV7 from the Power Supply and Signal Generation board. See NOTE below.

> NOTE: If the converter does not contain jumper STV7, you must wait 15 minutes after performing step 4 to allow the temperature detector circuit to stablize before proceeding.

4. Turn on converter by pressing its POWER pushbutton.

5. Using a digital voltmeter, measure and record the voltage at IC6 pin 7 on the Power Supply and Signal Generation board.

6. Add 0.6 volt to the voltage measured in step 5 to obtain the overtemperature trip-point voltage. Note that this voltage level will correspond to a turbopump motor winding temperature of approximately 158°F (70°C).

7. Using a digital voltmeter, measure the voltage at IC3 pin 5. Then adjust the Pump Overtemperature Trip Point control, P3, for a voltmeter indication equal to the overtemperature trip-point voltage which was calculated in step 6.

8. Turn off converter; remove the 41.5 ohm resistor; and then replace jumper STV7 which was removed in step 3.

9. This completes the pump overtemperature trip-point adjustment procedure.

5.6.4 MAXIMUM DRIVE FREQUENCY ADJUSTMENT (P1)

The converter's maximum drive frequency of 1250 Hz is set by the Maximum Drive Frequency control, P1. To adjust this control, see Fig. 5-11 and proceed as follows:

CAUTION

All measurements are referenced to board ground V01 which is ABOVE chassis ground. If using AC powered test equipment, float the equipment's AC ground to prevent short circuiting the converter.

1. Start the turbopump and allow the converter to switch to normal operation.

2. Using an oscilloscope or frequency counter, measure the converter's C1 clock frequency at IC8 pin 9, located on the Control and Status Indication board. Note that this frequency will be 48-times the converter's output drive frequency.

3. While monitoring the C1 clock frequency, adjust the Maximum Drive Frequency control, P1, for a clock frequency of exactly 60 kHz. (This frequency corresponds to a pulse-repetition-rate of 16.7 microseconds as observed on an oscilloscope. See waveform shown in Fig. 8-5.)

4. This completes the maximum drive frequency adjustment procedure.

5.6.5 PUMP SPEED MONITOR PULSE WIDTH ADJUSTMENT (P2)

The pulse width of one-shot multivibrator IC4, located on the Control and Status Indication board, is adjusted to be 500 microseconds in duration by the Pump Speed Monitor Pulse Width control, P2. To adjust this control, see Fig. 5-11 and proceed as follows:

CAUTION

All measurements are referenced to board ground V01 which is ABOVE chassis ground. If using AC powered test equipment, float the equipment's AC ground to prevent short circuiting the converter.

1. Start the turbopump and allow the converter to switch to normal operation.

2. Using an oscilloscope, observe the waveform at IC4 pin 3, located on the Control and Status Indication board.

3. While observing the oscilloscope, adjust the Pump Speed Monitor Pulse Width control, P2, for a pulse width of exactly 500 microseconds. See waveform shown in Fig. 8-5.

4. This completes the pump speed monitor pulse width adjustment procedure.

SECTION 6
DETAILED DESCRIPTION

6.1 TMP-50 OPERATING PRINCIPLE

The TURBOVAC TMP-50 is a turbomolecular pump designed to operate in the region of molecular flow. The operating principle of such a pump is as follows:

Gas molecules enter the pump's high vacuum inlet by virtue of their thermal motions (Fig. 6-1). Some gas molecules are then struck by the blades of the first rotor stage and tend to rebound in the desired pumping direction (i.e., toward the first stage of stator vanes). Note that the tip velocity of the rotor blades is of the same order of magnitude as the mean thermal velocity of the gas molecules. The molecules then rebound off the vanes of the first stator stage in such a direction as to increase the probability of their being favorably impelled by the blades of the second rotor stage. This process is repeated through all rotor/stator stages. The series of impacts statistically favors motion toward the exhaust port where the gas molecules are pumped and exhausted to atmosphere by a backing pump.

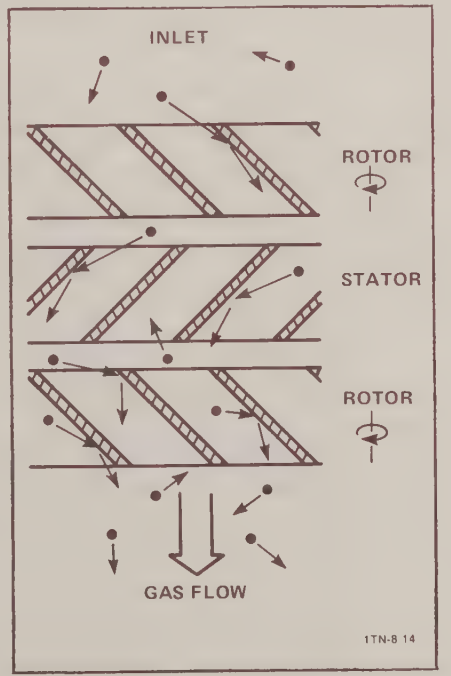


Figure 6-1. Side View of Three Rotor/Stator Stages

The ultimate pressure of turbomolecular pumps is influenced by the individual partial pressures of the different gases at the pump's exhaust port, and by the pump's compression ratio for these individual gas components. In the ultra-high vacuum range the ultimate total pressure is mainly determined by the amount of

hydrogen present. Note that the TMP-50 is specified to have a compression ratio for hydrogen of 10^2; therefore, in order for the TMP-50 to attain its specified ultimate pressure of 8×10^{-9} mbar, it is necessary to use a backing pump which is capable of maintaining a very low hydrogen partial pressure at the turbomolecular pump's exhaust port. A two-stage rotary vane pump is recommended for this purpose.

6.2 TMP-50 CONSTRUCTION

Figure 6-2 shows the TMP-50 as a single axial flow turbomolecular pump of vertical design.

The high vacuum intake port (1) is secured directly to the vacuum chamber by any one of three different flanges (KF40, LF65, and CF63). The type of intake flange supplied is identified by the pump's catalog number (refer to Table III Ordering Information at the front of this manual).

The gas to be pumped enters the intake port and passes through a wire-mesh inlet screen (2), which protects the pump from mechanical damage by small foreign objects down to approximately 0.06 inch (1.5 mm) in size.

Gas molecules then encounter the pump's rotor (4) and stator (3) assemblies. The rotor and stator have turbine blades around their circumference with each rotor/stator pair forming a pumping stage, so that the whole assembly is composed of a multitude of pumping stages mounted in series. The first rotor/stator pair forms the pump's vacuum stage. This stage is characterized by blades of large radial span with large blade angles. This design configuration provides a large annular inlet area and ensures maximum gas molecule capture for pumping. The gas captured by the upper vacuum stage is then transferred to the lower compression

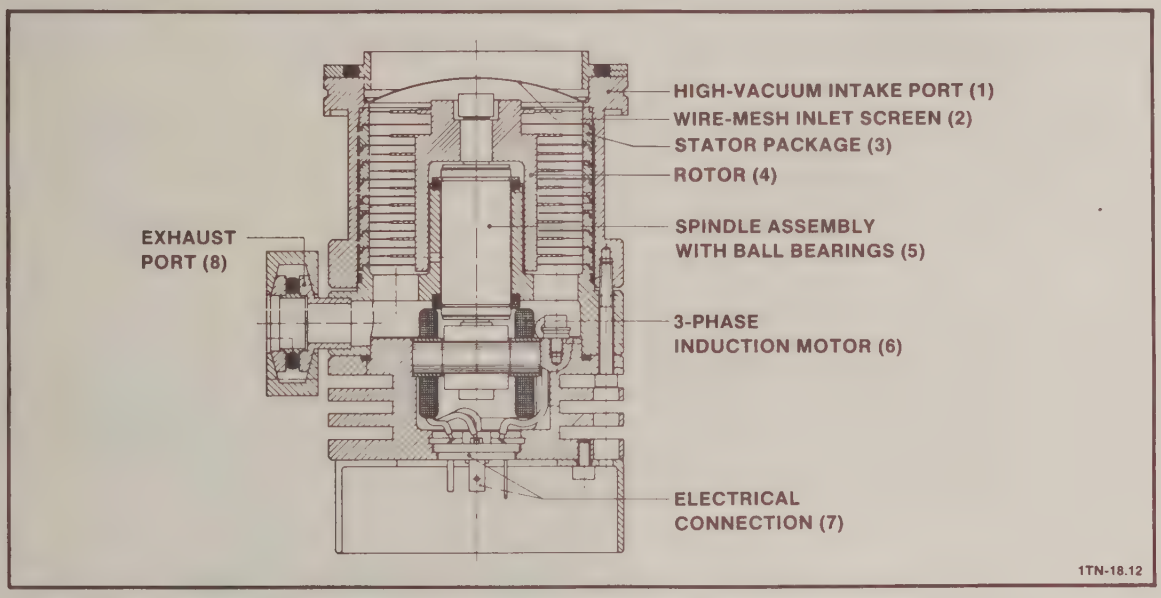


Figure 6-2. TMP-50 Cutaway View

stages where the gas molecules are compressed to fore-vacuum pressure. These compression stages are characterized by blades of short radial span with narrow blade angles, thus maximizing both average blade speed and compression.

The rotor shaft in the spindle assembly (5) is supported by two precision ball bearings lubricated with a special grease. Note that the bearings are lifetime lubricated, within the sealed spindle assembly, with a mean time between failure (MTBF) of approximately 20,000 hours. This unique lubricating system allows the pump to be mounted in any desired angular position.

The rotor is directly driven by a 3-phase, squirrel-cage induction motor (6). The motor and its spindle assembly with ball bearings are mounted in the fore-vacuum space, thus keeping the high-vacuum space free of any grease contaminants.

The electrical connection (7) to the induction motor is located at the bottom of the pump. In addition to inputting power to the

motor, this electrical connection also outputs temperature and rotational speed signals to the NT-50 Frequency Converter.

The motor is normally cooled by heat convection up to a maximum ambient air temperature of 122°F (50°C). When operating above this temperature, air-cooling and water-cooling options are available.

Generally, the pump is vented from the high-vacuum side either directly via the vacuum chamber, or via an intermediate flange mounted on the pump's inlet. Note that the CF63 flanged pump has an integrated KF10 venting port, located midway between the pump's intake and exhaust ports.

Gas exits the pump via the exhaust port (8) which is supplied with a type KF16 fitting.

6.3 FREQUENCY CONVERTER BASIC FUNCTIONS

Before discussing the specific operating principles of the NT-50, this section describes some of the basic functions performed by a frequency converter.

The major function of a frequency converter is to convert 50/60 Hz, single-phase power, into high-frequency, 3-phase AC power. This power conversion is necessary to operate the AC induction motor of a turbomolecular pump at its rated rotational speed. Induction motors require that their drive frequency be closely related to their actual rotational speed.

For the pump to achieve its rated rotational speed as quickly as possible, a frequency converter will start the pump motor from rest with a low drive frequency, and then slowly raise the drive frequency as the pump accelerates. This function causes the pump motor to operate at maximum torque during acceleration. Torque is a function of the motor's slip frequency, which is defined as the

difference between the applied drive frequency and the motor's actual rotational frequency. Up to a point, induction motor torque increases as the slip frequency increases; however, as the slip frequency continues to increase, torque ceases to increase, and for a low-slip, high-efficiency motor, torque actually begins to decrease.

In addition to varying the drive frequency, a frequency converter also varies its output voltage level so as to maintain the proper relationship between the motor's drive voltage and drive frequency (known as the "volts per Hertz" ratio). Induction motors require that the drive voltage be proportional to, and closely related to the drive frequency. A drive voltage which is too high or too low with respect to the drive frequency will result in reduced torque. Note, however, since the torque required to accelerate a pump is generally more than that required to maintain its operating speed, many frequency converters automatically reduce the amount of applied torque by lowering the drive voltage once normal operating speed has been achieved.

6.4 NT-50 OPERATING PRINCIPLES

The NT-50 Frequency Converter consists of the following three printed circuit boards: 1) the Power Supply and Signal Generation Board, 2) the Control and Status Indication Board, and 3) the Six-Step Inverter Board. See Fig. 6-3.

The following paragraphs in conjunction with the block diagram in Fig. 6-5, describe the basic operating principles of the NT-50 Frequency Converter. A more detailed description of these circuits is presented in Section 6.5.

The NT-50 uses the variable-frequency, variable-voltage technique to control the motor speed of its associated TMP-50 Turbomolecular Pump. This technique is based on the principle that the speed of an induction motor is determined by the motor's synchronous speed and slip frequency. The synchronous speed is related to the motor's drive frequency while slip is proportional to the load or

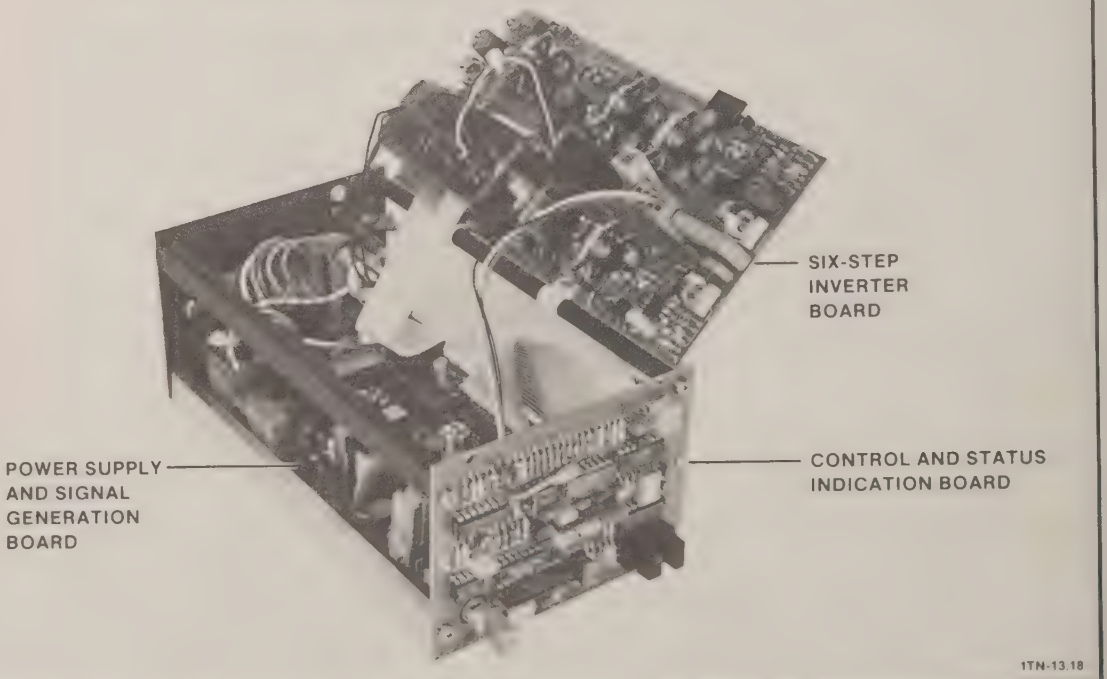


Figure 6-3. NT-50 Printed Circuit Board Locations

torque demand on the motor. The DC link method of power conversion is used to convert the AC power line into the required variable-frequency, variable-voltage, 3-phase power source. This method basically converts AC into DC, and then inverts the DC voltage onto the converter's three output lines in a sequence which synthesizes a 3-phase AC output signal. The term DC link refers to the DC voltage link between the input and output of the converter's voltage inverter stage.

The Intermediate DC Voltage Power Supply generates a DC voltage of between +250 and +370 volts, depending on the incoming AC line voltage level. When the converter is switched on, the AC line voltage is immediately rectified by a circuit which can be connected as either a standard bridge rectifier or a voltage doubler. This rectifier arrangement allows the converter to operate from line voltages of between either 90-140 V AC, or 180-265 V AC. The AC voltage range is selected by the proper placement of connector STV1.

The converter's control and switching circuits are powered by a switching type power supply which generates outputs of +10 and +7.5 volts.

An Intermediate DC Voltage Out of Range circuit inhibits the converter from operating when the intermediate DC voltage is below +150 volts or above +380 volts. This is accomplished by having this circuit's "IVOR" output cause the Output Disable Control circuit to apply a disable signal over the "ODIS" line to the Three Phase Logic Generator circuit.

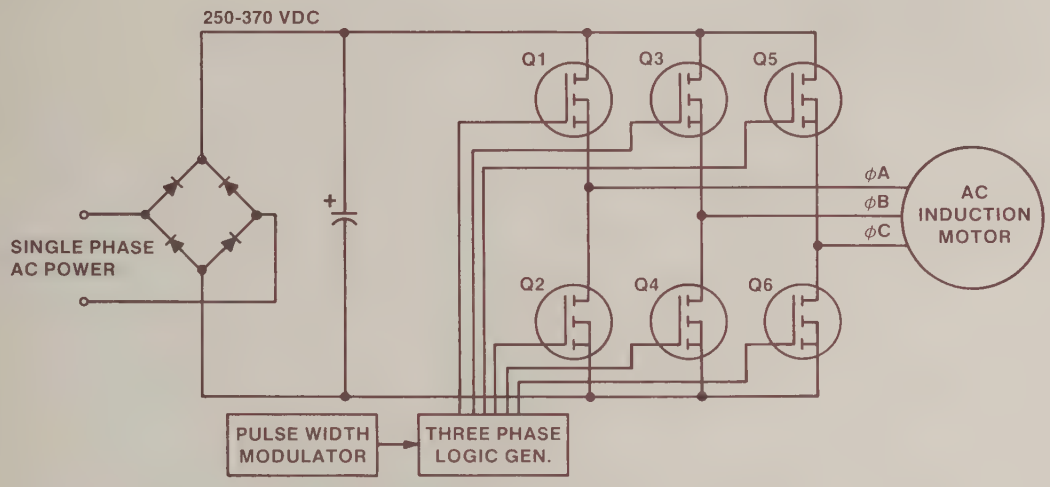
The pump is started by pressing the converter's START button. At this time the Output Disable Control circuit removes the disable signal from the Three Phase Logic Generator circuit which, in turn, begins to provide properly-timed, turn-on pulses to the Six-Step Inverter circuit.

Six switching FETs on the Six-Step Inverter board now begin to switch the intermediate DC voltage onto the converter's three output lines in a sequence determined by the Three Phase Logic Generator circuit. This switching sequence synthesizes a 3-phase AC power signal at the converter's output terminals. The NT-50 controls the mean value of its output voltage by pulse-width modulating the turn-on pulses applied to the switching FETs, while its output frequency is controlled by varying the frequency of the turn-on pulse sequence. Fig. 6-4 shows a simplified schematic of a pulse-width modulated, variable frequency, variable voltage six-step induction motor drive, along with its output voltage and current waveforms for a resistive load (connected in place of a motor). Note that the resultant current waveform of each output line resembles an AC signal, with each cycle consisting of six discrete steps - hence, the name six-step.

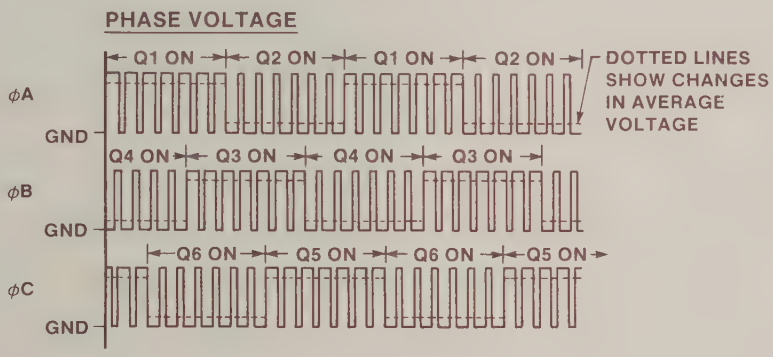
The pump motor also serves as a rotational speed and temperature sensor. To accomplish this, the Drive/Measure Interval Clock applies a pump-on/off signal through the Output Disable Control circuit to the Three Phase Logic Generator which, in turn, drives the pump for 1.2 seconds and then allows it to freewheel for 120 milliseconds. It is during the freewheeling time period that the pump's rotational speed and temperature measurements are made.

Pump rotational speed is detected by measuring the frequency of the voltage induced in one of the pump motor stator windings, while pump temperature is detected by measuring the voltage drop across the winding. Temperature measurements are based on the principle that the voltage drop across the motor stator winding is directly proportional to winding temperature.

If the motor stator winding temperature exceeds 158°F (70°C), the Pump Temperature Detector will apply a signal over the "OTP" line to the Overtemperature Failure Latch circuit which, in turn, will apply a disable signal through the Output Disable Control circuit to the Three Phase Logic Generator.



TRANSISTOR ON SEQUENCE (1, 4, 5) (1, 4, 6) (1, 3, 6) (2, 3, 6) (2, 3, 5) (2, 4, 5)



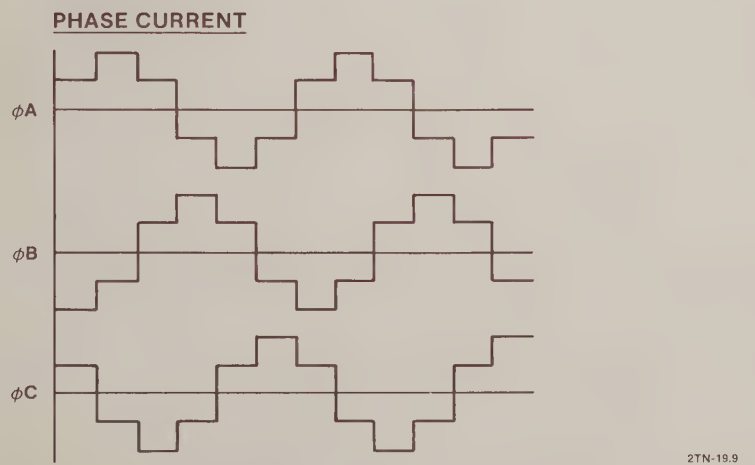


Figure 6-4. Six-Step Induction Motor Drive, Simplified Schematic with Voltage and Current Waveforms

The Pump Speed Detector, Pump Speed to Current Converter, and Pump Speed Monitor and Status Indication circuits function together to perform the following three functions: 1) The NORM indicator is turned on while the ACCEL indicator is turned off when the pump's rotational frequency reaches approximately 1000 Hz. 2) The drive frequency is varied in proportion to pump speed by controlling the clock "C1" output signal of the Drive Frequency Clock circuit. 3) The drive voltage is varied as a function of the motor's slip frequency by controlling the "PWR" output signal of the Slip Dependent Voltage Regulator circuit.

The Drive Frequency Clock circuit produces output pulses of between 9.6 and 60 kHz (corresponds to drive frequencies of between 200 and 1250 Hz). These output pulses are used to synchronize the operation of the Pulse Width Modulator with the Three Phase Logic Generator.

The converter's output voltage is varied between approximately 50 and 150 V AC by controlling the on-time of the switching FETs on the Six-Step Inverter Board. This is accomplished by pulse-width modulating the turn-on pulses applied to these FETs from the Three Phase Logic Generator circuit. Pulse-width modulation is achieved by applying properly timed, inhibit signals to the Three Phase Logic Generator from the Pulse Width Modulator. The Pulse Width Modulator, and thus the converter's output voltage, is controlled by either the Current Limiter circuit, or by the Slip Dependent Voltage Regulator.

The Current Limiter circuit monitors the current level in the Intermediate DC Voltage Power Supply, and then controls the operation of the Pulse Width Modulator such that this current level does not exceed a limit of approximately 140 mA.

The Slip Dependent Voltage Regulator circuit takes control of motor voltage at the beginning of normal operation. At this time, the drive frequency is being held constant at 1250 Hz by the Pump Speed

Monitor circuit; thus, the slip frequency of the pump motor will begin to decrease as the speed of the pump rises to meet the converter's maximum drive frequency.

As the slip frequency decreases, the Slip Dependent Voltage Regulator lowers the motor voltage to a more energy saving level since less torque is now required to maintain pump speed. In other words, if the Slip Dependent Voltage Regulator detects that motor slip is decreasing (indicating that too much motor torque is being applied), its PWR output will become more positive and decrease the motor voltage. And if the regulator detects that motor slip is increasing (indicating that the pump is being slowed down due to motor loading), its PWR output will go less positive and increase the motor voltage. Thus, the pump motor is always operating at its most energy efficient level under varying load conditions. Note, however, if the pump is loaded to the point where the Slip Dependent Voltage Regulator produces maximum motor voltage at a slip frequency of approximately 200 Hz, the Current Limiter circuit will retake control of motor voltage during normal operation.

After the most energy efficient motor voltage level has been established, the Slip Dependent Voltage Regulator then functions to maintain this voltage by monitoring both the applied motor voltage and the intermediate DC voltage levels, which are supplied over the "PDMV" and "LPPS" lines, respectively.

Pressing the STOP button shuts down the pump by sending a pump stop signal through the Output Disable Control circuit to the Three-Phase Logic Generator which, in turn, removes the turn-on pulses from the Six-Step Inverter circuit. Note that pressing the STOP button also resets the Overtemperature Failure Latch circuit and turns off the FAIL indicator.

6.5 NT-50 CIRCUIT DESCRIPTIONS

This section contains detailed descriptions of the circuits contained in the NT-50 Frequency Converter. Part location and electrical schematic diagrams of the converter's three printed circuit boards are illustrated in Figs. 8-2 thru 8-7.

6.5.1 POWER SUPPLY AND SIGNAL GENERATION BOARD

The Power Supply and Signal Generation board, mounted at the bottom of the converter package, contains the following circuits:

1. Power Supplies
2. Intermediate DC Voltage Monitor
3. Current Limiter
4. Pump Speed and Temperature Detectors
5. Temperature Detector Enable Delay
6. Pulse Width Modulator
7. Three Phase Logic Generator
8. Remote Control and Remote Normal Operation Sensing

Detailed descriptions of these circuits are presented in the following sections.

6.5.1.1 Power Supplies

The converter contains an unregulated Intermediate DC Power Supply and a regulated Switching Power Supply.

The Intermediate DC Power Supply consists of AC line filter L1, surge thermistor R2, bridge rectifier GI1, filter capacitors C7 and C8, and AC voltage select connector STV1. This supply generates an unregulated output of between +250 and +370 volts, depending on the level of the incoming AC line voltage.

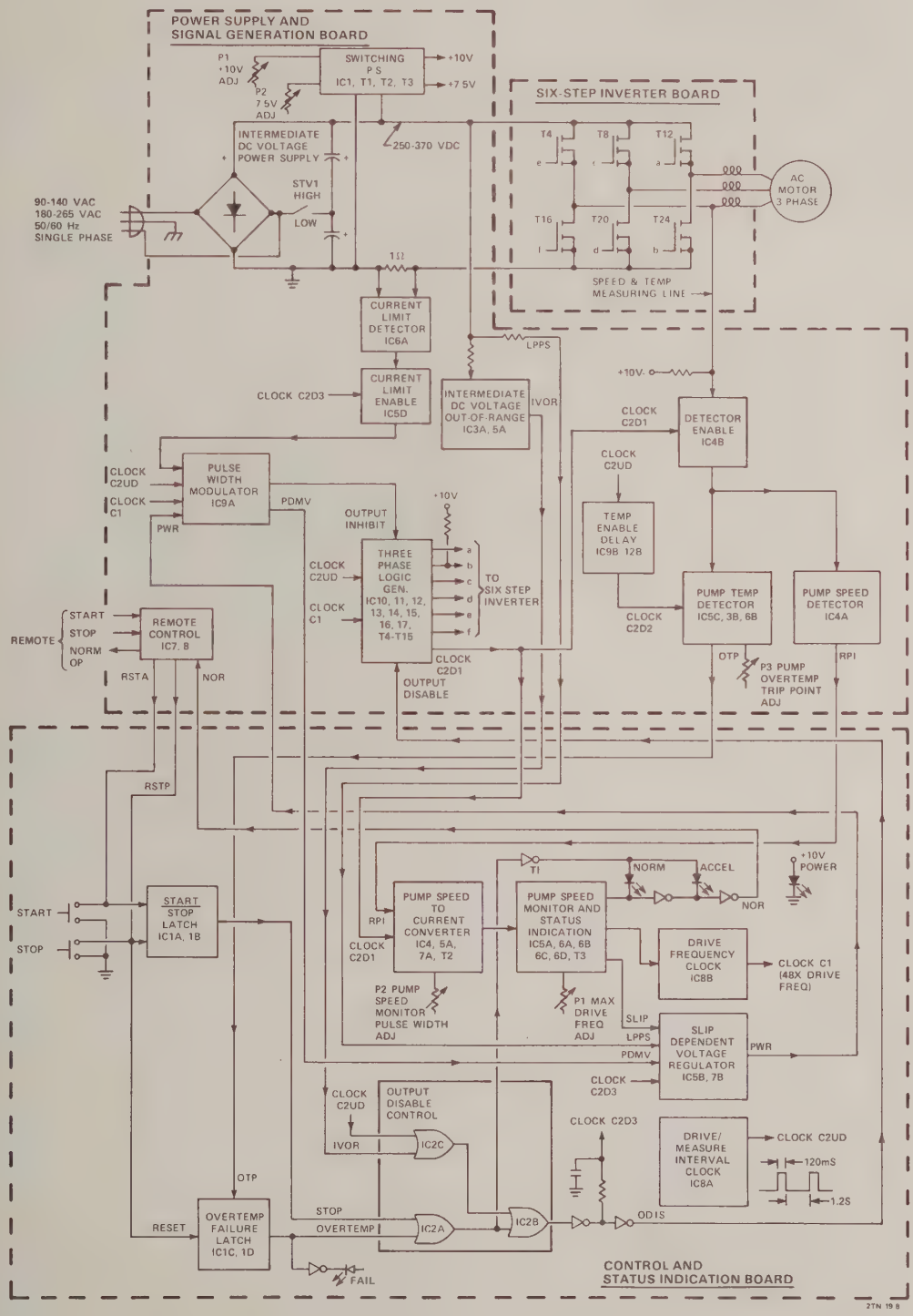


Figure 6-5. NT-50 Block Diagram

The Switching Power Supply consists of switching control IC1, switching transistors T1, T2, and T3, transformer TR1, and reference diode IC2. This power supply provides regulated outputs of +10 and +7.5 volts to the converter's control and switching circuits.

When the converter is switched on, the Intermediate DC Power Supply immediately rectifies the incoming AC line voltage by a circuit which can be connected as either a standard bridge rectifier or a voltage doubler. With voltage select connector STV1 connected in its LOW position (closed), the converter will operate from line voltages of between 90 and 140 V AC. And with STV1 set to its HIGH position (open), the converter can operate from line voltages of between 180 and 265 V AC. This rectifier arrangement produces an intermediate DC voltage of between +250 and +370 volts across capacitors C7 and C8, depending on the level of the incoming AC line voltage.

As soon as voltage is present on the intermediate DC voltage bus, the Switching Power Supply is activated through transistor T2 which applies voltage to IC1 pin 9. Then once the Switching Power Supply begins to operate, and the voltage across capacitor C17 reaches approximately +10 volts, transistor T1 will turn on, causing transistor T2 to turn off. IC1 is now powered by the voltage developed across capacitor C15.

Transistor T3 is now being switched on and off by IC1, pins 7 and 8, at a frequency which induces from transformer TR1 primary winding W1 into secondary winding W3 an AC voltage that, when rectified by diode D5, developes +10 volts across capacitor C17.

The switching frequency of transistor T3 is determined by the time period capacitor C11 is allowed to charge. Transistor T3 is pulsed on and off when the charge across capacitor C11 causes the voltage at IC1 pin 4 to exceed the reference voltage

at IC1 pin 3. At this time capacitor C11 is discharged and then allowed to recharge for the next cycle. The positive reference voltage at IC1 pin 3 is developed from the +4.2 volt output of IC1 pin 1 and the negative DC feedback voltage produced from transformer TR1 secondary winding W2. Potentiometer P1 controls the amount of the negative feedback voltage, and is adjusted to produce a power supply output of +10 volts across capacitor C17.

Reference diode IC2 provides a regulated reference output of +7.5 volts across capacitor C26. The reference voltage level is adjusted by potentiometer P2.

The voltage induced across winding W4 is rectified by diode D12, causing capacitor C30 to charge up to approximately +5 volts. This voltage is used to power optoisolators IC7 and IC8 of the Remote Control and Normal Operation Sensing circuit.

6.5.1.2 Intermediate DC Voltage Monitor

This circuit disables the converter by generating a logic High signal on the "IVOR" line whenever the intermediate DC voltage either goes below +150 volts or goes above +380 volts. The "IVOR" signal disables the converter by causing the Output Disable Control circuit, located on the Control and Status Indication board, to disable the Three Phase Logic Generator whenever the "IVOR" signal goes High.

With the intermediate DC voltage between +150 and +380, the voltages dropped across resistors R28, R27, R78, and R26 cause the output of comparator IC3A to be Low and analog switch IC5A to be turned on, thus making the "IVOR" line Low.

If the intermediate DC voltage rises above +380, the voltage at the non-inverting input of IC3A becomes more positive than the reference voltage at its inverting input. The output of comparator IC3A thus goes positive, and applies a High signal on the "IVOR" line through analog switch IC5A.

If the intermediate DC voltage drops below +150, the positive voltage applied to analog switch IC5A pin 13 becomes too low to keep the switch turned on; therefore, analog switch IC5A is turned off which causes the "IVOR" line to be pulled High through resistor R76.

6.5.1.3 Current Limiter

The Current Limiter circuit controls the converter's output voltage such that the pump motor's maximum current level is not exceeded. Note that during acceleration, this circuit maintains motor current at approximately 140 mA while slowly raising the motor voltage, thus producing maximum motor torque at a slip frequency of approximately 200 Hz (slip frequency is the difference between the motor's actual rotational frequency and its drive frequency).

The Current Limit circuit generates its output signal by having differential amplifier IC6A monitor the difference between the voltage dropped across intermediate-DC-current-sensing resistor R30 and a reference voltage across resistor R25. If the voltage across R30 goes more positive than the reference voltage, IC6A pin 1 will go positive. This positive voltage is applied through diode D15 to Pulse Width Modulator circuit IC9A pin 2 which, in turn, lowers the converter's output voltage to a level which will not cause the pump motor to draw more than approximately 140 mA of current.

The clock "C2D3" signal (by going High) enables the Current Limiter circuit shortly after the pump's drive interval begins by turning on analog switch IC5D. This clock signal then disables the Current Limit circuit (by going Low) during the pump's measure interval.

6.5.1.4 Pump Speed and Temperature Detectors

The pump motor serves as the rotational speed and temperature sensor for the Pump Speed and Temperature Detector circuits. To accomplish this, the pump is driven for 1.2 seconds and then allowed to freewheel for 120 milliseconds. It is during the freewheeling time period that pump speed and temperature measurements are made by the converter.

Pump rotational speed is detected by converting the frequency of the voltage generated by the pump's induction motor, into a series of trigger pulses whose pulse-repetition rate is proportional to the pump's rotational speed. These trigger pulses are applied over the "RPI" line to the Pump Speed to Current Converter circuit, located on the Control and Status Indication board.

Pump temperature is detected by measuring the voltage drop across the pump motor's stator winding. Temperature measurements are based on the principle that the voltage drop across the motor stator winding is directly proportional to winding temperature. If the pump temperature exceeds 158°F (70°C) a logic Low signal is applied over the "OTP" line to the Overtemperature Failure Latch circuit, located on the Control and Status Indication board.

During the pump's measure interval, the clock "C2D1" signal goes High and enables the Pump Speed and Temperature Detector circuits by turning off the open collector output of IC4B.

The feedback motor frequency signal is then applied over the "L1" line through resistors R47 and R46 and over limiting Zener diode D8 to the inverting input of comparator IC4A. As a result, IC4A applies to the "RPI" line a series of trigger pulses whose pulse-repetition rate is proportional to pump speed.

To sense pump temperature, a current from the converter's +10 volt power supply is applied over the "L1" line through the pump's motor stator winding to ground. The current path is through resistor R49, diode D6, and resistors R48 and R65. The resultant voltage drop across the motor winding is sensed over the "L1" line and applied to the inverting input of comparator IC3B through analog switch IC5C and amplifier IC6B.

If the voltage drop across the motor stator winding causes the voltage applied to the inverting input of IC3B to exceed the reference voltage applied to its non-inverting input, IC3B will then generate a logic Low overtemperature signal on the "OTP" line. Potentiometer P3 sets the temperature level at which the Low "OTP" signal is generated.

Note that the temperature measurement is delayed for approximately 40 mS after the beginning of the measure interval by having analog switch IC5C turned off. IC5C is turned on toward the end of the measure interval for approximately 80 mS by the clock "C2D2" signal generated by the Temperature Enable Delay circuit, IC12B pin 15.

6.5.1.5 Temperature Detector Enable Delay

The function of this circuit is to generate the clock "C2D2" signal. This clock signal delays the operation of the Pump Temperature Detector for approximately 40 mS after the beginning of the measure interval, allowing the temperature detector to operate toward the end of the measure interval for approximately 80 mS.

At the start of the measure interval, the clock "C2UD" signal goes High and triggers one-shot multivibrator IC9B, causing its NOT Q output, pin 9, to go Low. Also at this time, the clock "C2UD" signal turns on analog switch IC5B which, in turn, applies a ground signal to the reset input IC12B, pin 12. This ground signal enables IC12B to now be triggered.

Approximately 40 mS after one-shot multivibrator IC9B was triggered, its NOT Q output, pin 9, goes back High and triggers J-K flip-flop IC12B, causing its Q output, pin 15, to go High and turn on analog switch IC5C of the Pump Temperature Detector circuit.

At the end of the measure interval, the clock "C2UD" signal returns Low and turns off analog switch IC5B. A High signal from pull-up resistor R33 is then applied to the reset input of J-K flip-flop IC12B, causing its Q output, pin 15, to go Low and turn off analog switch IC5C.

6.5.1.6 Pulse Width Modulator

The Pulse Width Modulator circuit is capable of varying the converter's output voltage between approximately 50 and 150 V AC by pulse-width modulating the turn-on pulses from the Three Phase Logic Generator circuit. Pulse-width modulation is accomplished by inhibiting the output of the Three Phase Logic

Generator for a time period determined by the Pulse Width Modulator. The amount of pulse-width modulation, and thus the converter's output voltage, is controlled by either the Current Limiter, or the Slip Dependent Voltage Regulator. Proper timing of the Pulse Width Modulator's output inhibit signals is provided by the clock "C2UD" and clock "C1" signals.

The Pulse Width Modulator consists of IC9A, which is a controllable, one-shot multivibrator capable of generating at pins 6 and 7 output pulses from less than 1 microsecond to 50 microseconds in duration.

The NOT Q output from IC9A, pin 7, is applied through resistor R60 to the inhibit input of the Three Phase Logic Generator circuit (IC15 pin 12), while the Q output from IC9A, pin 6, is applied over the "PDMV" line to the Slip Dependent Voltage Regulator, located on the Control and Status Indication board.

One-shot multivibrator IC9A is triggered on by the clock "C1" signal applied to pin 3, while the duration of its output pulse is determined by a positive voltage applied to pin 2. Note that by making the voltage at IC9A pin 2 more positive, the pulse duration of IC9A is made smaller, thereby reducing the converter's output voltage.

The Current Limiter circuit controls the converter's output by applying its positive output voltage through diode D15 to IC9A pin 2.

The Slip Dependent Voltage Regulator controls the converter's output by applying its positive "PWR" output signal through resistor R72 and diode D14 to IC9A pin 2.

During the measure interval when the clock "C2UD" signal is High, capacitor C31 is charged positive. Then when "C2UD" goes

back Low during the drive interval, capacitor C31 slowly discharges through resistor R56. This slow discharge provides a "soft restart" of the Pulse Width Modulator at the beginning of each drive interval.

6.5.1.7 Three Phase Logic Generator

This circuit provides the properly-timed, pulse-width modulated, turn-on pulses to the six switching FETs on the Six-Step Inverter board.

Timing of the Three Phase Logic Generator circuit is provided by the clock "C1" signal which is running at 48-times the converter's output drive frequency. The clock "C1" signal is applied to divide-by-eight counter IC10 pin 1 which, in turn, provides at pin 5 trigger pulses that are 6-times the converter's output drive frequency. These trigger pulses are applied to six individual divide-by-six counters consisting of J-K flip-flops IC11A, IC11B, IC12A, AND Gates IC13A thru D, and XOR Gates IC14A thru D. These divide-by-six counters are interconnected such that they form a rotating field generator circuit whose outputs are shifted by 120 degrees with respect to each other.

The six outputs of the rotating field generator circuit are then applied through tri-state hex buffer IC15, and buffers IC16 and IC17, to switching transistors T4 thru T15. These transistors when switched on and off, produce the pulses which control the conduction of the switching FETs on the Six-Step Inverter board.

All outputs of tri-state buffer IC15 can be made to go Low by applying a logic High to its inhibit input. The Pulse Width

Modulator circuit can thus control the conduction time of the FETs on the Six-Step Inverter board by applying properly timed logic High inhibit signals to buffer IC15 pin 12.

All outputs of tri-state buffer IC15 can also be turned off (high impedance state) by applying a logic High to its disable input. The Output Disable Control circuit, located on the Control and Status Indication board, can thus disable the pump by applying a logic High disable signal over the "ODIS" line to buffer IC15 pin 4. A disable signal is generated whenever: 1) the pump is stopped, 2) an overtemperature failure occurs, 3) the intermediate DC voltage level is either too high or too low, or 4) the measure interval begins.

When the measure interval begins, the clock "C2UD" signal will go High and disable the pump through the Output Disable Control circuit as described above. However, due to the high output impedance state of IC15, the clock "C2UD" will also generate at IC15 pin 9 a turn-on signal for FET T24 over the "SUE3" line. This turn-on signal is produced when the clock "C2UD" signal goes high and cuts off diode D17 which, in turn, allows the inputs of buffers IC16F and IC17F to be pulled High through resistor R63. Thus only FET T24 is turned on during the measure interval which, in turn, connects one of the pump's motor stator windings to the converter's Pump Speed and Temperature Detector circuits.

6.5.1.8 Remote Control and Remote Normal Operation Sensing

The Remote Control circuit generates the logic signals required to start and stop the converter when using external start/stop switches.

The Start/Stop circuit, located on the Control and Status Indication board, is enabled by applying a logic High on the

"RSTP" line. This High signal is generated by optoisolator IC8, which is turned on by connecting either a jumper or a normally-closed switch to rear panel STOP terminals 2 and 3. Note that the Start/Stop circuit will not operate without IC8 turned on.

To remotely start the converter, a ground signal is applied to the rear panel START terminal. Optoisolator IC7 is thus turned on which applies a logic Low signal to the "RSTA" line.

To remotely stop the converter, the connection made between the rear panel STOP terminals is momentarily opened. Optoisolator IC8 is thus turned off which removes the logic High signal from the "RSTP" line.

The remote operation relay provides normally-open and normally-closed contacts at rear panel terminals 4, 5, and 6. This relay is energized when the "NOR" line is pulled Low by the Pump Speed Monitor circuit, located on the Control and Status Indication board.

6.5.2 CONTROL AND STATUS INDICATION BOARD

The Control and Status Indication board, mounted behind the front cover, contains the following circuits:

1. Drive/Measure Interval Clock
2. Start/Stop Latch
3. Output Disable Control
4. Pump Speed to Current Converter
5. Pump Speed Monitor and Status Indication
6. Drive Frequency Clock
7. Slip Dependent Voltage Regulator
8. Overtemperature Failure Latch

Detailed descriptions of these circuits are contained in the following sections.

6.5.2.1 Drive/Measure Interval Clock

The Drive/Measure Interval Clock circuit generates the clock "C2UD" signal. This circuit consists of IC8A which is connected as a free running, astable multivibrator. IC8A produces at pin 5, a signal that is Low for 1.2 seconds (drive interval) and is High for 120 milliseconds (measure interval). The function of this clock signal is to switch the converter between its drive and measure intervals.

Note that from the clock "C2UD" signal, the clock "C2D1", clock "C2D2", and clock "C2D3" signals are generated. These different clock signals are required to achieve the necessary drive/measure timing relationships within the converter. These relationships are shown in Fig. 6-6. The generation and function of these clock signals are described throughout the NT-50 circuit description sections of this manual.

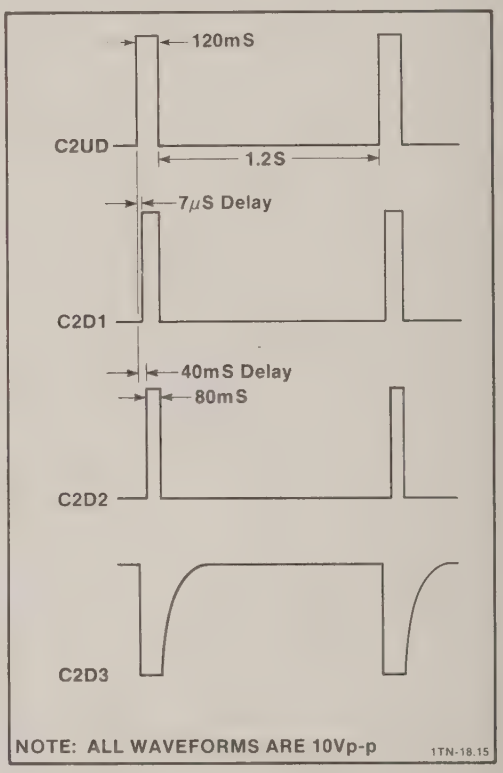


Figure 6-6. Clock "C2UD", "C2D1", "C2D2", and "C2D3" Timing and Polarity Relationships

6.5.2.2 Start/Stop Latch

NOTE: For the Start/Stop Latch circuit to operate properly, the Remote Control circuit's "RSTP" output line must be held High by a jumper or normally-closed switch connected to the converter's rear panel STOP terminals.

The Start/Stop Latch circuit is composed of a set-reset flip-flop consisting of cross-coupled NAND Gates IC1A and B. This circuit produces a High output at NAND Gate IC1A pin 3 when the pump is stopped, and a Low output when the pump is started. The output state of this flip-flop is changed by applying a momentary logic Low signal to either its set (IC1A pin 1) or reset (IC1B pin 6) input.

Pressing the converter's START button applies a Low to NAND Gate IC1B pin 6, causing the output of NAND Gate IC1A pin 3 to go Low. If the output of the Failure Latch circuit (IC1D pin 11) is also Low, the "ODIS" output line of the Output Disable Control circuit (inverter IC3B pin 15) will then go Low and remove the output disable signal from the Three Phase Logic Generator. The pump is then started when the Three Phase Logic Generator begins to provide turn-on pulses to the Six-Step Inverter circuit.

Pressing the STOP button applies a Low to NAND Gate IC1A pin 1, causing the output of NAND Gate IC1A pin 3 to go High which, in turn, causes the "ODIS" output line of the Output Disable Control circuit (inverter IC3B pin 15) to also go High and disable the Three Phase Logic Generator circuit. The pump is then stopped when the Three Phase Logic Generator removes the turn-on pulses from the Six-Step Inverter circuit. Note that pressing the STOP button also discharges capacitor C1. Thus the pump cannot be restarted during the 3 second interval it takes for this capacitor to recharge.

Remote starting is accomplished by providing a switch closure at the converter's remote START input. This switch closure causes the Remote Control circuit's "RSTA" line to go Low which, in turn, causes the Start/Stop Latch circuit to start the pump. Note that for the converter to operate, the "RSTP" line must be held High by a normally closed switch connected to the converter's rear panel STOP terminals.

To remotely stop the pump, the normally High "RSTP" line is made to go Low by opening the switch connected to the converter's remote STOP terminals. This causes the Start/Stop Latch circuit to stop the pump.

6.5.2.3 Output Disable Control

This circuit removes drive voltage from the pump by applying a logic High signal over the "ODIS" line to the output disable input of the Three Phase Logic Generator circuit, located on the Power Supply and Signal Generation board.

The inputs of OR Gates IC2A, B, and C monitor the outputs of the Drive/Measure Interval Timer (C2UD), Intermediate DC Voltage Out-Of-Range (IVOR), Start/Stop, and Overtemperature Failure Latch circuits. If the output of any one or more of these circuits goes High, the "ODIS" line will also go High and cause all outputs of the Three Phase Logic Generator circuit to go to their high-impedance state. Drive voltage is thus removed from the pump for as long as the "ODIS" line is High.

The front panel ACCEL and NORM indicators are disabled by turning off transistor T1. This occurs when the output of OR Gate IC2A goes High when either the pump is stopped or when there is an overtemperature failure.

The Output Disable Control circuit also generates the clock "C2D3" signal by inverting the clock "C2UD" signal at the output of inverter IC3A.

6.5.2.4 Pump Speed to Current Converter

This circuit controls the conduction of transistor T2 such that this transistor's collector current is a linear indication of the pump's actual rotational speed.

The trigger pulses on the "RPI" line are applied through capacitor C4 to one-shot multivibrator IC4. For every trigger pulse, IC4 generates at pin 3 a pulse of 500 microseconds in duration. These pulses are passed through analog switch IC5A during the measure interval, and are then integrated by resistor R8 and capacitor C9 into a DC voltage that is proportional to the pump's actual rotational speed. This DC voltage is buffered by IC7A which provides a variable current source for the base of transistor T2. Thus the collector current of transistor T2 is proportional to the pump's actual rotational speed.

The collector current of transistor T2 flows through resistors R17 and either R13 or R15, depending on the output state of comparator IC6B of the Pump Speed Monitor and Status Indication circuit.

6.5.2.5 Pump Speed Monitor and Status Indication

This circuit provides outputs that: 1) control the operation of the ACCEL and NORM indicators, 2) control the converter's output frequency via the Drive Frequency Clock circuit, and 3) control the pump's motor voltage during normal operation via the Slip Dependent Voltage Regulator circuit.

With the pump stopped, the logic High output from OR Gate IC2A turns on analog switch IC5C which, in turn, applies a ground to the non-inverting input of Schmitt-trigger IC6C, causing its output to be Low at the moment the pump is started. The High signal from OR Gate IC2A also disables the NORM and ACCEL indicators by turning off transistor T1. Thus when the the output of OR Gate IC2A goes Low when the START button is pressed, analog switch IC5C is turned off and transistor T1 is turned on, causing ACCEL LED LD3 to light.

Also while the pump is stopped, the voltage dropped down by resistor R9, after being buffered by IC6A and IC6D, causes transistor T3 to charge C11 to a voltage level that makes astable multivibrator IC8B, of the Drive Frequency Clock circuit, operate at its lowest output frequency of 9.6 kHz (corresponds to a converter output drive frequency of 200 Hz).

When the pump is started and while it accelerates, the collector current of transistor T2 will increase and cause the voltage dropped down by resistor R13 to increase in proportion to the pump's actual rotational speed. This increasing voltage drop across resistor R13 is applied to buffer IC6A which, in turn, causes buffer IC6D to increase the conduction of transistor T3, thus charging capacitor C11 to a positive voltage level that is proportional to the pump's actual rotational speed. This steadly increasing positive voltage across capacitor C11 is applied to astable multivibrator IC8B, causing the clock "C1" signal to increase in frequency which,

in turn, increases the converter's drive frequency as the pump accelerates.

The voltage dropped down by resistor R13 is also applied to the inverting input of comparator IC6B and compared to a reference voltage at its non-inverting input. During acceleration the voltage dropped down by resistor R13 will be more positive than the reference voltage. As a result, the output of IC6B will be about zero volts which blocks the conduction of diode D4. However, as soon as the converter switches over to normal operation, the output of comparator IC6B will move out of its null-position and begin to go positive. This occurs when the voltage dropped down by resistor R13 becomes less positive than the reference voltage from potentiometer P1. Switchover to normal operation occurs at a drive frequency of 1250 Hz. Note that the pump's rotational frequency at this time will be approximately 1000 Hz.

At the moment the output of comparator IC6B moves out of its null-position and begins to go positive, diode D4 conducts and places resistor R15 in the collector circuit of transistor T2. The voltage dropped down by R13 in now held constant on an ongoing basis as the result of the voltage dropped across resistor R15; thus, the drive frequency is also held constant. Also at this time, diode D8 conducts and applies a positive voltage to the non-inverting input Schmitt-trigger IC6C, causing its output to go High which, in turn, lights NORM LED LD2 and turns off ACCEL LED LD3. A Low signal is then applied from inverter IC3F to the "NOR" line, causing the normal operation relay, located on the Power Supply and Signal Generation board, to energize.

At the beginning of normal operation, the voltage across resistor R15 will steadly increase as motor slip begins to decrease. (Motor slip decreases as the result of the pump's rotational speed increasing to meet the applied drive

frequency.) The voltage across resistor R15 is thus an indication of motor slip, and is used to control the operation of the Slip Dependent Voltage Regulator.

If the pump is loaded, the voltage across R15 will decrease as motor slip increases. If the slip frequency increases to approximately 200 Hz, the output of comparator IC6B will go back into its null-position and block diode D4. The voltage dropped down by resistor R13 is now able to decrease and lower the drive frequency if the pump continues to be slowed down. At this time, motor-voltage control is taken over by the Current Limiter circuit. If the pump is heavily loaded, causing it to be slowed down to a rotational frequency of less than 500 Hz, the NORM indicator is turned off and the ACCEL indicator is turned back on. The ACCEL indicator is turned on when the output of buffer IC7A drops low enough in voltage to cause Schmitt-trigger IC6C to switch back to its Low state.

6.5.2.6 Drive Frequency Clock

This circuit consists of astable multivibrator IC8B which generates the clock "C1" signal. This clock circuit provides trigger pulses that are 48-times the converter's output drive frequency to the Pulse Width Modulator and the Three Phase Logic Generator circuits.

The frequency of the clock "C1" signal is controlled by a positive voltage applied to IC8B pin 12 from capacitor C11 of the Pump Speed Monitor. When a pump is started from rest, the Pump Speed Monitor increases the frequency of the clock "C1" signal from a minimum of 9.6 kHz to a maximum of 60 kHz (corresponds to a converter output frequency of between 200 and 1250 Hz) by increasing the voltage applied to IC8B pin 12 in proportion to the pump's actual rotational frequency.

If a pump is restarted while it is still rotating, the Pump Speed Monitor will charge capacitor C11 to a voltage that will cause the converter to quickly produce a drive frequency that matches the pump's rotational frequency.

6.5.2.7 Slip Dependent Voltage Regulator

The Slip Dependent Voltage Regulator circuit controls motor voltage by applying its "PWR" output signal to the Pulse Width Modulator, located on the Power Supply and Signal Generation board. The function of this circuit is to lower motor voltage to a more energy saving level once normal operation begins, since less torque is now required to maintain pump speed. The Slip Dependent Voltage Regulator then continues to control the motor voltage as a function of motor slip. In other words, as the motor slip decreases the motor voltage will be decreased. And if the motor slip increases (due to pump loading) the motor voltage will be increased.

During acceleration the "PWR" output of the Slip Dependent Voltage Regulator is zero volts due to the zero volt output of comparator IC6B of the Pump Speed Monitor circuit. However, after the converter reaches its maximum drive frequency, motor slip will decrease as the speed of the pump rises to meet the converter's output drive frequency. At this time, the output of IC6B will begin to go positive and produce a voltage drop across resistor R15 that is inversely proportional to the amount of motor slip.

Differential amplifier IC7B senses the voltage drop across resistor R15 through resistors R14 and R16, and then generates a positive voltage on the "PWR" line that is proportional to the voltage drop across resistor R15. For example, as motor slip decreases, the voltage across R15 will increase and cause the "PWR" signal to become more positive and reduce motor

voltage. And as motor slip increases, the voltage across R15 will decrease and cause the "PWR" signal to become less positive and increase motor voltage.

After the correct motor voltage has been established, the Slip Dependent Voltage Regulator then functions to maintain this voltage level by causing the "PWR" signal to move in a direction that compensates for any undesired changes in motor voltage. Motor voltage information is supplied to IC7B as the "PDMV" signal from the Pulse Width Modulator. The "PDMV" signal is passed through analog switch IC5B during the measure interval, and is then integrated by resistor R34 and capacitor C22 into a DC voltage that is proportional to motor voltage.

The Slip Dependent Voltage Regulator also maintains the converter's output voltage against AC line voltage fluctuations. To accomplish this, IC7B monitors the intermediate DC voltage level on the "LPPS" line, and then changes the "PWR" signal in a direction that compensates for any changes in the intermediate DC voltage level.

As described above, if motor slip increases due to the pump being loading, the Slip Dependent Voltage Regulator will increase motor voltage by making its "PWR" signal less positive. If the pump continues to be loaded, causing the "PWR" signal to reach zero volts (corresponds to full motor voltage at a slip frequency of approximately 200 Hz), motor-voltage control is taken over by the Current Limitier circuit. At this time, the drive frequency is allowed to decrease such that the slip frequency is maintained at approximately 200 Hz as the pump slows down.

6.5.2.8 Overtemperature Failure Latch

This circuit functions to stop the pump and latch the converter in its off state if the Pump Temperature Detector circuit, located on the Power Supply and Signal Generation board, detects that the pump motor has exceeded a temperature of 158°F (70°C).

The Overtemperatrue Failure Latch circuit consists of cross-coupled NAND Gates IC1C and IC1D which form a set-reset flip-flop. The output of this flip-flop (IC1D pin 11) is normally Low. However, if the "OTP" signal from the Pump Temperature Detector goes low, IC1D pin 11 then goes High and causes the "ODIS" output of the Output Disable Control circuit to also go High which, in turn, disables the converter and stops the pump.

Also at this time, the output of inverter IC3C goes Low and turns on FAIL LED LD1.

Pressing the converter's STOP button will reset the Over-temperature Latch circuit and turn off the FAIL indicator by applying a Low signal to IC1C pin 8. Note, however, that if the pump temperature is still too high when the STOP button is pressed, this latch circuit will not reset and the FAIL indicator will remain on.

6.5.3 SIX-STEP INVERTER BOARD

This board contains six FET switching circuits which switch the intermediate DC voltage onto the converter's three output lines in a sequence determined by the Three Phase Logic Generator circuit. This switching sequence synthesizes a 3-phase AC voltage at the converter's output terminals (see Fig. 6-4). The converter's output voltage level is controlled by pulse-width modulating the turn-on pulses applied to the switching circuits, while the converter's output drive frequency is controlled by varying the frequency of the turn-on pulse sequence.

The following circuit description refers to FET T24 and its associated gate drive circuit. Except where noted, this description is applicable to all six FET switching circuits.

The turn-on signal from the Three Phase Logic Generator circuit is coupled through capacitor C31 and pulse transformer TR6 into the gate drive circuit of FET T24. The resultant positive-going pulse developed across pulse transformer TR6 winding 3-6 causes non-inverting amplifier array IC6 to latch on via positive feedback resistor R55. Current source transistor T21 is then turned on, causing FET T24 to be turned on.

The removal of the turn-on signal from the Three Phase Logic Generator circuit, results in a negative-going pulse at the output of pulse transformer TR6, which resets amplifier IC6 to its off state. Current sink transistor T22 is then turned on, causing FET T24 to be turned off.

Overcurrent protection is provided by transistor T23. This transistor monitors the voltage drop across resistor R60, and if this voltage drop exceeds approximately 0.55 volt (2.5 amperes), transistor T23 will turn on and reset amplifier IC6 to its off state through diode D42.

The gate drive circuits of FETs T16, T20, and T24 are connected to the ground side of the Intermediate DC Voltage Power Supply, and can therefore be powered directly from the +10 volt output of the converter's Switching Power Supply through diodes D25, D32, and D39. However, since the gate drive circuits of FETs T4, T8, and T12 are connected to the positive side of the Intermediate DC Voltage Power Supply, their power source must be +10 volts higher than the intermediate DC voltage level. This is accomplished by full-wave rectifying the voltage developed across pulse transformer winding 4-5, and then adding this DC voltage to intermediate DC voltage level.

Inductor L1 and resistor R68 dampen the rise time of the current through the output stages, and thereby ensure an adequate time for their overcurrent protection circuits to react.

Diode D46 along with diodes D8, D16, D24, D31, D38, and D45 recirculate the inductive energy developed by the pump during braking back into the intermediate DC voltage bus.

For the pump to function as the converter's rotational speed and temperature detector, FET T24 is turned on during the measure interval by a turn-on signal applied over the "SUE3" line from the Power Supply and Signal Generation board. Thus the rotational frequency and temperature signals, developed across the stator winding connected between motor lines L1 and L3, are applied over sensing line "L1" to the Pump Speed and Temperature Detector circuits.

NOTES

SECTION 7
TROUBLESHOOTING

WARNING

The frequency converter employs voltages which are dangerous and may be fatal if contacted. Please note that the converter's circuit board ground is approximately 160 volts above chassis ground; therefore, exercise extreme caution when working inside the converter. Also, to reduce the possibility of electrical shock, always connect the converter's chassis to a low-impedance ground.

WARNING

If the turbomolecular pump has been exposed to toxic gases, the pump could be contaminated with dangerous chemicals. In such cases, use the proper precautions when working on the pump to prevent inhaling or coming in contact with these chemicals.

CAUTION

Since the frequency converter's printed circuit board ground is above chassis ground by about 160 volts, float the AC line cord ground connection of any AC powered test equipment to prevent short circuiting the converter.

The cause of most maintenance problems can be resolved by using the Troubleshooting Chart contained in Table 7-1. To use this chart, first locate the symptom of the problem, isolate the trouble area, then perform the recommended corrective action(s). The "References" column lists Figures and Sections in this manual that are helpful in correcting the problem.

Part locating diagrams and replacement parts for both the TMP-50 and NT-50, are contained in Section 8.

The electrical schematics of the NT-50 are also contained in Section 8 (Figs. 8-3, 8-5, and 8-7). These schematics contain useful troubleshooting information in the form of voltage levels and waveforms.

TROUBLESHOOTING TABLE OF CONTENTS

Symptom	Page
1. POWER indicator does not light	7-3
2. FAIL indicator lights and cannot be turned off even after repeatedly pressing STOP	7-4
3. ACCEL indicator does not light after pressing START	7-4
4. NORM indicator does not light within 10 minutes after pressing START	7-5
5. ACCEL indicator lights during operation	7-6
6. Turbopump does not start	7-6
7. Turbopump is noisy or vibrates	7-7
8. Turbopump becomes oily	7-7
9. Turbopump fore-vacuum pressure is too high ($>10^{-2}$ mbar)	7-8
10. Pumping speed is insufficient	7-9
11. Turbopump does not produce the desired working pressure	7-10
12. Turbopump emits pinging noises during venting	7-10

TABLE 7-1. TROUBLESHOOTING CHART

Symptoms	Trouble Area	Probable Cause	Recommended Corrective Action	References
1. POWER indicator does not light.	a. AC power	Converter not receiving AC power.	Check for presence of voltage at AC service outlet.	
	b. Fuse	Fuse blown because of a short circuit within converter.	Check for short in intermediate DC power supply.	Fig. 8-3 Sect. 6.5.1.1
			If using AC powered test equipment, float their AC line cord ground connection to prevent short circuiting converter.	
		Current rating of fuse was wrong for the applied AC line voltage.	Replace fuse with the correct current rating.	Sect. 3.3.1
	c. POWER indicator	POWER LED burned out.	Check for +10 V at POWER LED. If +10 V is present, replace LED.	Fig. 8-5
	d. Power supply	+10 V switching power supply on Power Supply and Signal Generation Board defective.	Remove jumper STV8 and check for a power supply output of +10 V. If no output is found, trouble-shoot supply or replace board.	Fig. 8-3 Sect. 6.5.1.1
		Short circuit on the +10 V buss.	Isolate +10 V power supply by removing jumper STV8, then locate area of short circuit. Repair or replace defective board.	Figs. 8-3, 8-5 and 8-7

TABLE 7-1. TROUBLESHOOTING CHART (Continued)

Symptoms	Trouble Area	Probable Cause	Recommended Corrective Action	References
2. FAIL indicator lights and cannot be turned off even after repeatedly pressing STOP.	a. Electrical connections	Turbopump not connected to converter.	Connect turbopump to converter using its four-conductor cable. Note that it will take about 3 minutes for the converter to recover before the FAIL indicator can be turned off.	Sect. 3.3.6
		Defective pump cable.	Repair or replace cable.	Fig. 8-8
	b. Turbopump	Pump has overheated due to gas overloading.	Pump may need additional cooling.	Sect. 3.4.3
			If pump is fan or water cooled, ensure that these devices are operating properly.	
			Refer to Symptoms 5 & 9.	
	c. Power Supply and Signal Generation board	Pump Temperature Detector circuit defective.	Troubleshoot this circuit or replace board.	Fig. 8-3 Sect. 6.5.1.4
	d. Control and Status Indication board	Overtemperature Failure Latch circuit defective.	Troubleshoot this circuit or replace board.	Fig. 8-5 Sect. 6.5.2.8
3. ACCEL indicator does not light after pressing START.	a. Rear panel connections	External start/stop bypass jumper not installed.	Connect a jumper to rear panel STOP terminals 2 & 3 when not using remote control.	Fig. 3-2 Sect. 3.3.4
	b. AC voltage select jumper STV1, located on the Power Supply and Signal Generation board	Jumper STV1 is in the wrong position.	Place jumper in position that corresponds to the converter's AC input voltage as described in Section 3.3.1.	Fig. 3-1 Sect 3.3.1
	c. Front panel controls	Operation error.	Allow 3 seconds to elapse after turning on the converter or after stopping the pump before pressing the START button.	Sect. 4.2 Sect. 4.4.5
	d. Control and Status Indication board	Start/Stop, Output Disable Control, or Status Indication circuit defective.	Troubleshoot these circuits or replace board.	Fig. 8-5 Sect. 6.5.2.1 Sect. 6.5.2.2 Sect. 6.5.2.4

TABLE 7-1. TROUBLESHOOTING CHART (Continued)

Symptoms	Trouble Area	Probable Cause	Recommended Corrective Action	References
4. NORM indicator does not light within 10 minutes after pressing START.	a. High-vacuum space	Vacuum chamber too large.	Pump down chamber with backing pump before starting turbopump.	Sect. 4.3
			Larger turbopump may be required.	
		Leak in vacuum chamber.	Leak test vacuum chamber.	
		Venting valve open.	Close venting valve.	
	b. Fore-vacuum space	Fore-vacuum pressure too high.	Refer to Symptom 9.	
	c. Pump cable	Pump cable is longer than 328 ft. (100 m).	Shorten pump cable.	
			If cable length must be greater than 328 ft. (100 m), a larger diameter cable is required to reduce its voltage drop. Contact Leybold-Heraeus for correct pump cable required.	
	d. Power Supply and Signal Generation board	Pump Speed Detector circuit defective.	Troubleshoot this circuit or replace board.	Fig. 8-3 Sect. 6.5.1.4
	e. Control and Status Indication board	Pump Speed to Current Converter, Pump Speed Monitor, or Status Indication circuit defective.	Troubleshoot these circuits or replace board.	Fig. 8-5 Sect. 6.5.2.3 Sect. 6.5.2.4
	f. Turbopump	Pump motor rotation direction is incorrect.	Check pump motor direction of rotation as described in Section 3.3.7.	Sect. 3.3.7
		Pump rotor cannot turn due to obstruction in rotor blades or defective motor bearings.	Remove pump from system. Check for smooth running of rotor. If the rotor does not turn or turns stiffly, disassemble pump as described in Section 5.4 to determine cause of obstruction. If necessary, replace rotor/spindle assembly as described in Section 5.4.5.	Sect. 5.4 Sect. 5.4.5

TABLE 7-1. TROUBLESHOOTING CHART (Continued)

Symptoms	Trouble Area	Probable Cause	Recommended Corrective Action	References
5. ACCEL indicator lights during operation, indicating that the pump has been slowed down below 40% of its rated rotational speed.	a. High-vacuum space	High process gas loading.	Larger turbopump may be required.	
		Leak in vacuum chamber.	Leak test vacuum chamber.	
	b. Fore-vacuum space	Fore-vacuum pressure too high.	Refer to Symptom 9.	
	c. Converter	Converter became defective, causing its output voltage to drop.	Troubleshoot converter using its schematic diagrams. Repair defective circuit or replace defective board.	Figs. 8-3, 8-5 and 8-7 Sect. 6.4
	d. Turbopump	Pump rotor cannot turn due to obstruction in rotor blades or defective motor bearings.	Remove pump from system. Check for smooth running of rotor. If the rotor does not turn or turns stiffly, disassemble pump as described in Section 5.4 to determine cause of obstruction. If necessary, replace rotor/ spindle assembly as described in Section 5.4.5.	Sect. 5.4 Sect. 5.4.5
		Pump motor stator defective.	Using an ohmmeter, check the stator's winding resistance. The resistance measured between any two poles should be approximately 50 ohms.	
6. Turbopump does not start.	a. Converter	No output voltage from converter.	Refer to Symptoms 1, 2, & 3.	
	b. Turbopump	Pump rotor cannot turn due to obstruction in rotor blades or defective motor bearings.	Remove pump from system. Check for smooth running of rotor. If the rotor does not turn or turns stiffly, disassemble pump as described in Section 5.4 to determine cause of obstruction. If necessary, replace rotor/ spindle assembly as described in Section 5.4.5.	Sect. 5.4 Sect. 5.4.5
		Pump motor stator defective.	Using an ohmmeter, check the stator's winding resistance. The resistance measured between any two poles should be approximately 50 ohms.	

TABLE 7-1. TROUBLESHOOTING CHART (Continued)

Symptoms	Trouble Area	Probable Cause	Recommended Corrective Action	References
7. Turbopump is noisy or vibrates.	a. Pumping system	Turbopump runs in natural frequency with pumping system.	Change configuration of pumping system.	
			Install damping bellows at pump's intake and exhaust ports.	Sect. 1.4.6 Sect. 3.4.1 Sect. 3.4.2
	b. Turbopump	Pump motor bearings are defective or rotor has become unbalanced.	Remove pump from system. Check for smooth running of rotor. If rotor turns stiffly, is noisy, or turns irregularly, replace rotor/spindle assembly as described in Section 5.4.5.	Sect. 5.4.5
8. Turbopump becomes oily.	a. Backing pump fore-vacuum valve	Backing pump oil got into turbopump due to defective fore-vacuum line shut-off valve.	Ensure that fore-vacuum line valve automatically closes when backing pump is shut off.	Sect. 3.4.2
	b. Venting system	Turbopump is not being properly vented upon shutdown.	Ensure that venting valve opens after turbopump is switched off.	Sect. 3.4.4
		Repeated venting from the fore-vacuum side.	Vent from the high-vacuum side.	Sect. 4.6
	c. Turbopump	Turbopump running too slow, allowing oil vapors to migrate into high-vacuum area.	Ensure that turbopump is operating at its rated rotational speed.	
	d. System configuration	Oil is backstreaming while backing pump is roughing down the system.	Rough system through a separate line rather than through the turbopump.	
			Add an adsorption trap to the foreline.	

TABLE 7-1. TROUBLESHOOTING CHART (Continued)

Symptoms	Trouble Area	Probable Cause	Recommended Corrective Action	References
9. Turbopump Fore-vacuum pressure too high (>10^{-2} mbar).	a. Vacuum gauge	Vacuum gauge defective.	Ensure that the vacuum gauge is operating correctly before assuming a problem exists in the pumping system.	
	b. Backing pump	Backing pump defective or too small.	Check operation of backing pump as described in its manual. A larger pump may be necessary.	Sect. 3.4.2
	c. Fore-vacuum line	Line too long.	Use shorter line.	
		Conductance of line is inadequate.	Check for restrictions in line. Ensure that inside diameter of line is adequate.	
	d. Fore-vacuum space	Fore-vacuum line leaky.	Leak test components in fore-vacuum line.	
	e. High-vacuum space	Leak in vacuun chamber.	Leak test vacuum chamber.	
	f. Venting system	Venting valve open.	Ensure that venting valve closes when turbopump is switched on.	Sect. 3.4.4 Sect. 4.6
		Venting valve leaky.	Leak test venting valve.	
	g. Turbopump	Leak around pump housing or electrical connector.	Leak test turbopump.	

TABLE 7-1. TROUBLESHOOTING CHART (Continued)

Symptoms	Trouble Area	Probable Cause	Recommended Corrective Action	References
10. Pumping speed insufficient.	a. High-vacuum space	Vacuum chamber too large.	Pump down chamber with backing pump before starting turbopump.	Sect. 4.3
			Larger turbopump may be required.	
	b. Fore-vacuum space	Fore-vacuum pressure too high.	Refer to Symptom 9.	
	c. Turbopump	Pump contaminated.	Clean pump as described in Section 5.3.	Sect. 5.3
			Refer to Symptom 8.	
		Wire-mesh inlet screen located at inlet port clogged.	Remove pump from system and clean wire-mesh inlet screen.	
		Pump leaky.	Leak test pump.	
		Motor bearing friction too high.	Remove pump from system. Turn rotor by hand and check for smooth running. If rotor turns stiffly, replace rotor/spindle assembly as described in Section 5.4.5.	Sect. 5.4.5
		Pump not assembled correctly.	Perform pump run-up test as described in Section 5.4.7. If necessary, disassemble and then reassemble pump as described in Section 5.4.	Sect. 5.4.7 Sect. 5.4

TABLE 7-1. TROUBLESHOOTING CHART (Continued)

Symptoms	Trouble Area	Probable Cause	Recommended Corrective Action	References
11. Turbopump does not produce desired working pressure.	a. Vacuum gauge	Vacuum gauge defective.	Ensure that the vacuum gauge is operating correctly before assuming a problem exists in the pumping system.	
	b. Vacuum system	Vacuum system dirty or outgassing.	Clean and/or bakeout vacuum system.	Sect. 4.7
		Vacuum system leaky.	Leak test vacuum system.	
	c. Fore-vacuum space	Fore-vacuum pressure too high ($>10^{-2}$ mbar).	Refer to Symptom 9.	
	d. Turbopump	Pump leaky.	Leak test pump.	
		High-vacuum space contaminated.	Clean pump as described in Section 5.3.	Sect. 5.3
		Pump is outgassing.	Bakeout CF flanged pump using bakeout jacket. For KF and LF flanged pumps, use hot-air gun.	
		Wrong high-vacuum gasket.	In ultra-high vacuum applications ($<10^{-7}$ mbar), ensure that either VITON or CF gaskets are used.	
		Motor bearing friction too high.	Remove pump from system. Turn rotor by hand and check for smooth running. If rotor turns stiffly, replace rotor/spindle assembly as described in Section 5.4.5.	Sect. 5.4.5
		Pump not assembled correctly.	Perform pump run-up test as described in Section 5.4.7. If necessary, disassemble and then reassemble pump as described in Section 5.4.	Sect. 5.4.7 Sect. 5.4
12. Turbopump emits pinging noises during venting.	Rotor blades	Rotor blades are hitting stator disks due to incorrectly assembled pump, bent or out-of-line rotor blades.	Disassemble pump as described in Section 5.4 and check that pump is assembled correctly. Also check alignment of rotor blades as described in Section 5.4.5.4.	Sect. 5.4 Sect. 5.4.5.4

SECTION 8
PARTS LISTS AND DIAGRAMS

8.1 GENERAL INFORMATION

This section contains parts lists, part location diagrams, and the NT-50 Frequency Converter electrical schematics. Note that Catalog Numbers for the turbopump, the frequency converter, and various accessory items are contained in Table III Ordering Information, located in the front of this manual.

8.2 PART ORDERING INFORMATION

Replacement parts can be ordered from the Order Services Department of Leybold-Heraeus in Export, PA or from your nearest Leybold-Heraeus representative.

When ordering a replacement part, please give its part number and description as listed in the TMP-50 or NT-50 Parts List. Also, include the model and serial number of your particular unit.

8.3 TMP-50 PARTS LIST

When ordering replacement parts for the TMP-50 Turbomolecular pump, see Fig. 8-1 and refer to Table 8-1.

8.4 NT-50 PARTS LISTS AND SCHEMATICS

When ordering replacement parts for the NT-50 Frequency Converter, see Figs. 8-2 thru 8-7 and refer to Tables 8-2 thru 8-4.

The schematics of the NT-50 are shown in Figs. 8-3, 8-5, and 8-7.

TABLE 8-1. TMP-50 PARTS LIST*

Item	Part Number	Description
1	200-17-187	Rotor/Spindle Assembly, Complete
2	200-17-114	Stator Ring, Narrow (73 x 6.6 mm)
3	200-17-115	Stator Ring, Wide (73 x 8.1 mm)
4	200-17-116	Stator Ring, with Hole (73 x 6.6 mm)
5	200-17-117	Stator Disk Half (71 x 0.3 x I.D. 29 mm)
6	200-17-118	Stator Disk Half (71 x 0.3 x I.D. 39 mm)
7		Wire-Mesh Inlet Screen:
	200-17-169	KF40 (41 x 0.3 mm)
	200-17-170	LF65 (71 x 8 mm)
	200-17-171	CF63 (63 x 10 mm)
8	200-17-126	Support Ring, Top (26 x 0.5 mm)
9	200-17-179	Support Ring, Bottom (26 x 1.5 mm)
10	200-17-127	Shim (26 x 0.1 mm)
11	200-17-132	Retainer Ring
12**	200-17-142	Motor Casing
13**	200-17-120	Motor Stator
14**	500-17-243	Current Feedthrough
15**	201-03-202	Allen Head Bolt (M4 x 8 mm), DIN 912
16**	221-01-201	Flat Washer (A4.3), DIN 125
17**	221-09-107	Serrated Lock Washer (A4.3), DIN 6798
18**	200-17-143	Ground Wire, Yellow/Green
19	239-50-510	O-Ring (18 x 5 mm), Buna-N
20	200-17-134	O-Ring (22 x 2.5 mm), Silicone
21	239-52-115	O-Ring (66 x 2 mm), Buna-N
22		O-Ring, High Vacuum Inlet:
	239-50-115	KF40 (42 x 5 mm), Buna-N
	239-70-510	LF65 (70 x 5 mm), VITON
--	200-29-979	Pump Cable, 10 ft. (3 m)

* For Catalog Numbers of various accessory items, refer to Table III Ordering Information, located at the front of this manual.

** These parts make up the motor housing with stator, and are replaced together as a complete assembly.

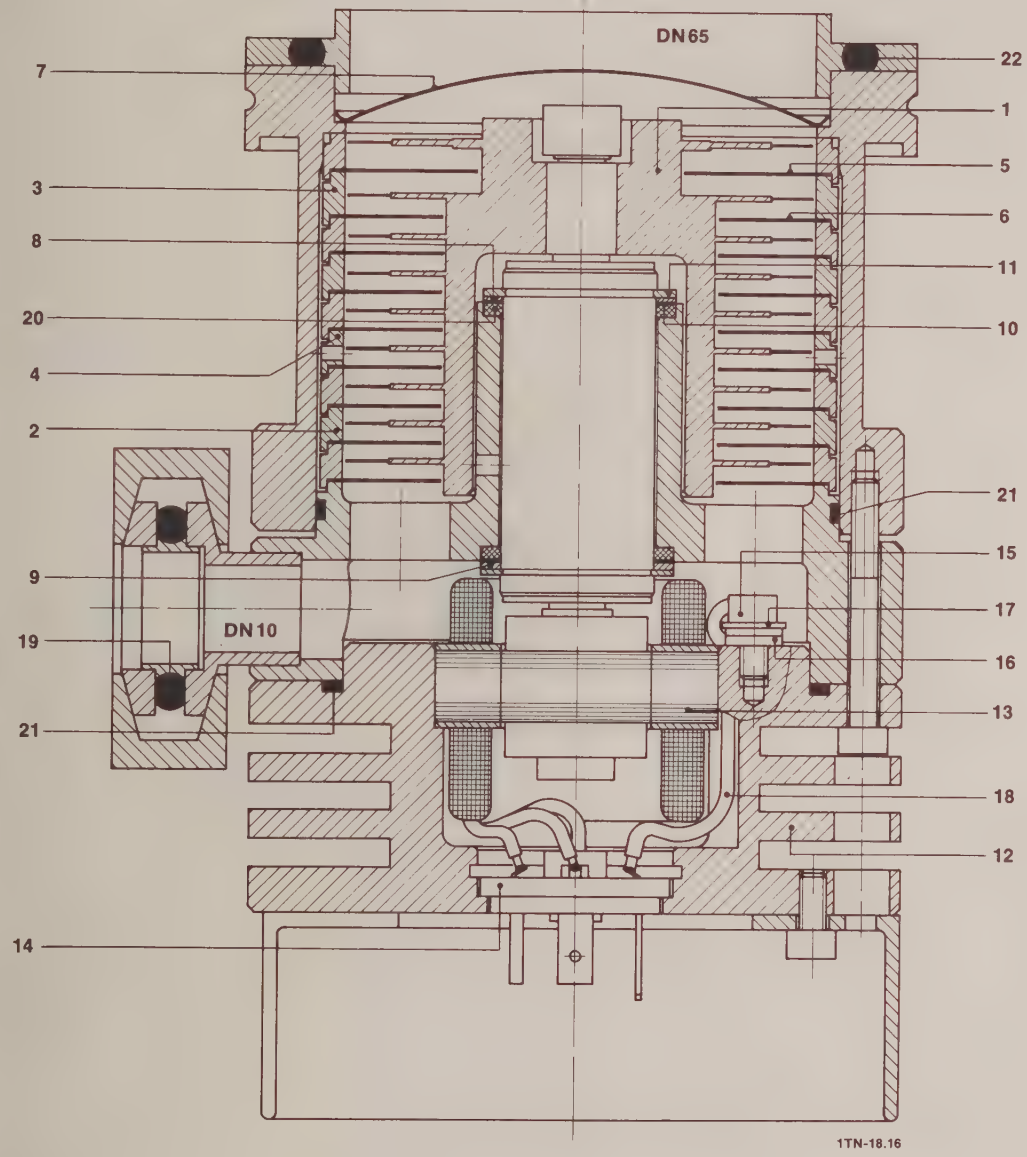


Figure 8-1. TMP-50 Part Locations

TABLE 8-2. NT-50 POWER SUPPLY AND SIGNAL GENERATION BOARD PARTS LIST*

Item	Part Number	Description
--	200-29-825	Complete Printed Circuit Board
D1	----	Zener Diode, ZPD 18
D2 thru D7	----	Diode, MR816
D8	510-43-225	Zener Diode, ZPD 5.6
D11	510-43-603	Diode, BAV19
D12	----	Diode, MR816
D13 thru D17	510-43-605	Diode, 1N4148
GI1	----	Diode Bridge, BY224
IC1	533-20-017	IC, TDA4600, Switching Regulator
IC2	533-20-038	IC, TL431, Shunt Regulator
IC3	533-21-246	IC, LM393, Dual Differential Comparator
IC4	533-21-246	IC, LM393, Dual Differential Comparator
IC5	533-20-022	IC, 4066, Quad Bilateral Switch
IC6	722-39-282	IC, CA3260, Op Amp
IC7	533-20-141	IC, CNY17, Optoisolator
IC8	533-20-141	IC, CNY17, Optoisolator
IC9	722-39-806	IC, 14528, Dual Monostable Multivibrator
IC10	722-39-807	IC, 14520, Dual Synchronous Up Counter
IC11	533-20-155	IC, 4027, Dual J-K Flip-Flop
IC12	533-20-155	IC, 4027, Dual J-K Flip-Flop
IC13	533-20-003	IC, 4081, Quad 2-Input AND Gate
IC14	722-39-803	IC, 4070, Quad 2-Input XOR Gate
IC15	722-39-805	IC, 4502, Tri-State Hex Inverter
IC16	533-20-198	IC, 4050, Hex Buffer
IC17	533-20-198	IC, 4050, Hex Buffer
T1	533-21-223	Transistor, BUX87
T2	533-21-223	Transistor, BUX87
T3	533-21-223	Transistor, BUX87
T4 thru T9	200-29-776	Transistor, ZTX652
T10 thru T15	200-29-777	Transistor, ZTX752

* See Fig. 8-3 for component type numbers not listed in this table.

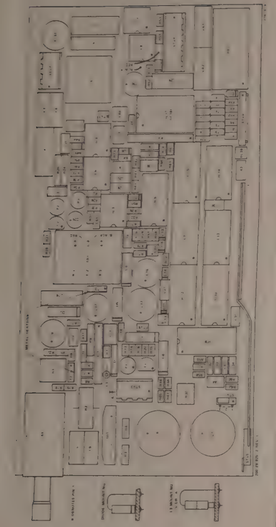


Figure 8-2. NT-50 Power Supply and Signal Generation Board, Part Locations

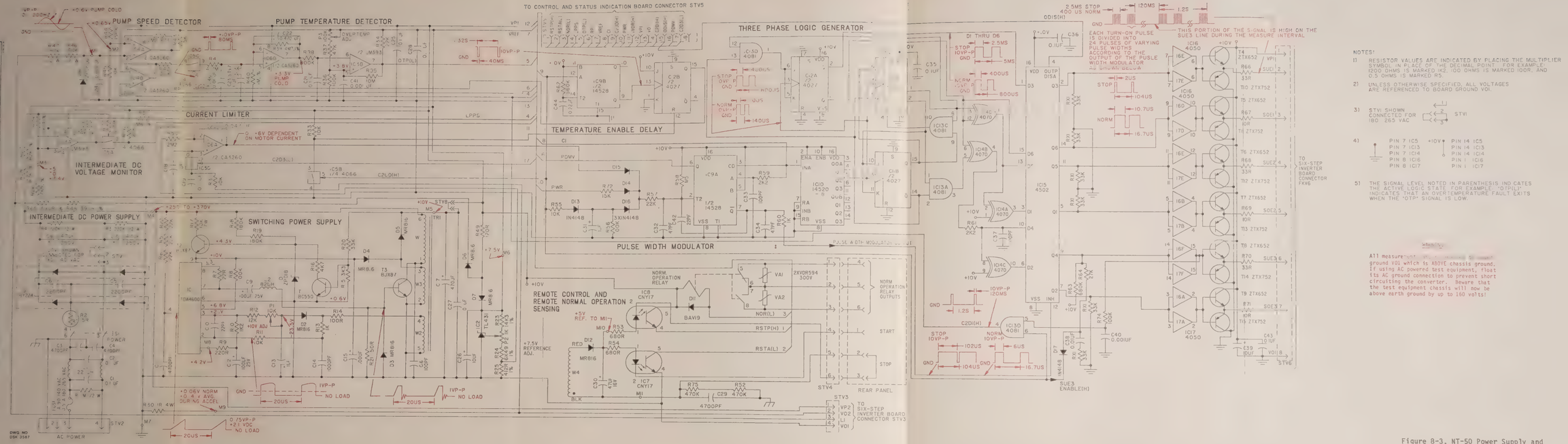

PUMP SPEED DETECTOR
PUMP TEMPERATURE DETECTOR
CURRENT LIMITER
INTERMEDIATE DC VOLTAGE MONITOR
INTERMEDIATE DC POWER SUPPLY
SWITCHING POWER SUPPLY
TEMPERATURE ENABLE DELAY
THREE PHASE LOGIC GENERATOR
PULSE WIDTH MODULATOR
REMOTE CONTROL AND REMOTE NORMAL OPERATION SENSING
TO CONTROL AND STATUS INDICATION BOARD CONNECTOR STV5
TO SIX-STEP INVERTER BOARD CONNECTOR STV3
TO SIX-STEP INVERTER BOARD CONNECTOR FX16
REAR PANEL
AC POWER
DWG NO DSK 3567

Figure 8-3. NT-50 Power Supply and Signal Generation Board, Schematic

TABLE 8-3. NT-50 CONTROL AND STATUS INDICATION BOARD PARTS LIST*

Item	Part Number	Description
--	200-29-826	Complete Printed Circuit Board
D1	510-43-605	Diode, 1N4148
D2	----	Zener Diode, ZPD 6.8
D3 thru D8	510-43-605	Diode, 1N4148
D9	510-43-353	Diode, BAT41
D10	510-43-353	Diode, BAT41
D11	510-43-605	Diode, 1N4148
IC1	722-39-157	IC, 4011, Quad 2-Input NAND Gate
IC2	533-20-200	IC, 4071, Quad 2-Input OR Gate
IC3	722-39-422	IC, 75468, Driver Array
IC4	722-39-704	IC, 7555, General Purpose Timer
IC5	533-20-022	IC, 4066, Quad Bilateral Switch
IC6	722-39-281	IC, LM324, Op Amp
IC7	722-39-282	IC, 3260, Op Amp
IC8	722-39-703	IC, 7556, Dual General Purpose Timer
T1	533-21-195	Transistor, BC560
T2	533-21-195	Transistor, BC560
T3	533-21-196	Transistor, BC550

* See Fig. 8-5 for component type numbers not listed in this table.

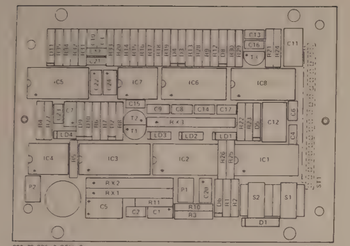


Figure 8-4. NT-50 Control and Status Indication Board, Part Locations

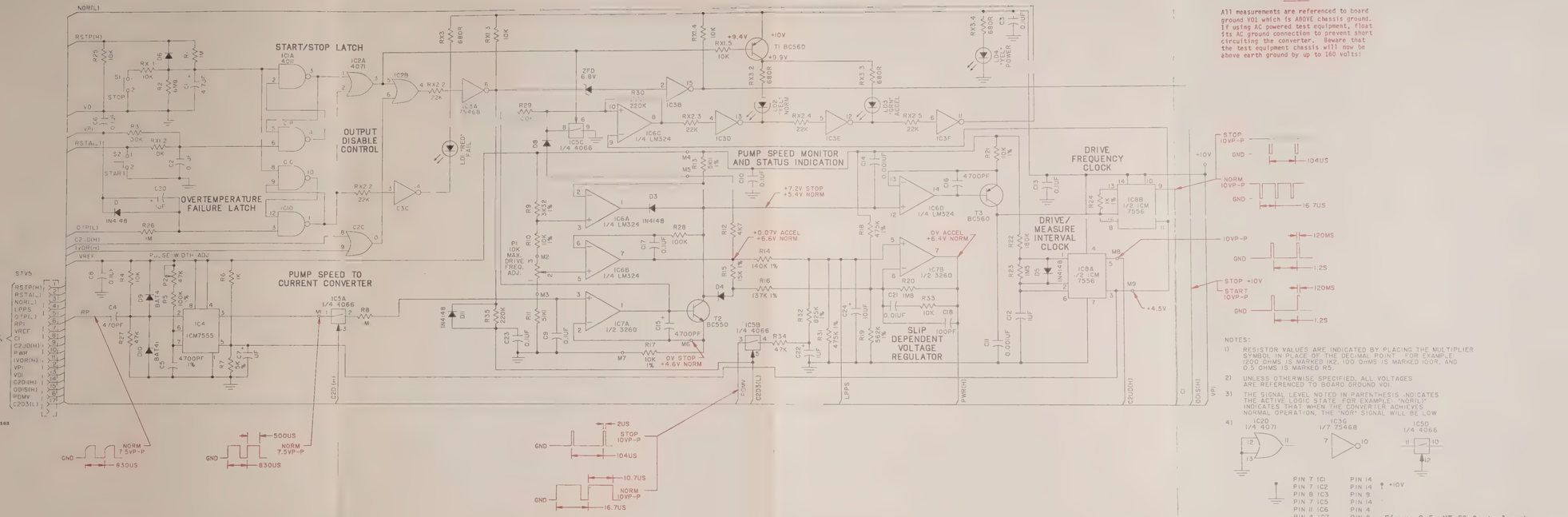

START/STOP LATCH
OUTPUT DISABLE CONTROL
OVERTEMPERATURE FAILURE LATCH
PUMP SPEED TO CURRENT CONVERTER
PUMP SPEED MONITOR AND STATUS INDICATION
DRIVE FREQUENCY CLOCK
DRIVE/ MEASURE INTERVAL CLOCK
SLIP DEPENDENT VOLTAGE REGULATOR
TO POWER SUPPLY AND SIGNAL GENERATION BOARD CONNECTOR ST5
DWG NO DSK 3568
WARMING
All measurements are referenced to board ground V01 which is ABOVE chassis ground. If using AC powered test equipment, float its AC ground connection to prevent short circuiting the converter. Beware that the test equipment chassis will now be above earth ground by up to 160 volts!
NOTES:
1) RESISTOR VALUES ARE INDICATED BY PLACING THE MULTIPLIER SYMBOL IN PLACE OF THE DECIMAL POINT. FOR EXAMPLE: 1200 OHMS IS MARKED 1K2, 100 OHMS IS MARKED 100R, AND 0.5 OHMS IS MARKED R5.
2) UNLESS OTHERWISE SPECIFIED, ALL VOLTAGES ARE REFERENCED TO BOARD GROUND V01.
3) THE SIGNAL LEVEL NOTED IN PARENTHESIS INDICATES THE ACTIVE LOGIC STATE. FOR EXAMPLE: "NOR(L)" INDICATES THAT WHEN THE CONVERTER ACHIEVES NORMAL OPERATION, THE "NOR" SIGNAL WILL BE LOW
4) IC2D 1/4 4071 IC5G 1/7 75468 IC5D 1/4 4066
PIN 7 IC1 PIN 14 PIN 7 IC2 PIN 14 PIN 8 IC3 PIN 9 PIN 7 IC5 PIN 14 PIN 11 IC6 PIN 4 PIN 4 IC7 PIN 8

Figure 8-5. NT-50 Control and Status Indication Board, Schematic

TABLE 8-4. NT-50 SIX STEP INVERTER BOARD PARTS LIST*

Item	Part Number	Description
----	200-29-827	Complete Board
D1, D9, D17	----	Diode, BAX12A
D2, D10, D18	----	Diode, BAX12A
D3, D11, D19	510-43-353	Diode, BAT41
D4, D12, D20, D27, D34, D41	510-43-353	Diode, BAT41
D5, D13, D21, D28, D35, D42	510-43-605	Diode, 1N4148
D6, D14, D22, D29, D36, D43	----	Diode, BAX12A
D7, D15, D23, D30, D37, D44	----	Diode, MR816
D8, D16, D24, D31, D38, D45	----	Diode, UES1306
IC1, IC2, IC3, IC4, IC5, IC6	533-20-198	IC, 4050, Hex Buffer
T1, T5, T9, T13, T17, T21	200-29-776	Transistor, ZTX652
T2, T6, T10, T14, T18, T22	200-29-777	Transistor, ZTX752
T3, T7, T11, T15, T19, T23	533-21-196	Transistor, BC550
T4, T8, T12, T16, T20, T24	200-29-791	FET, BUZ41A

* See Fig. 8-7 for component type numbers not listed in this table.

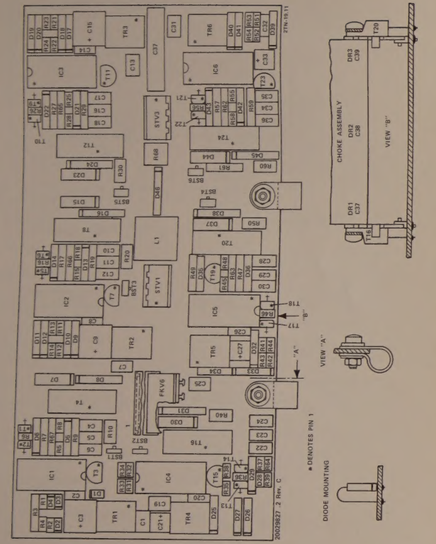
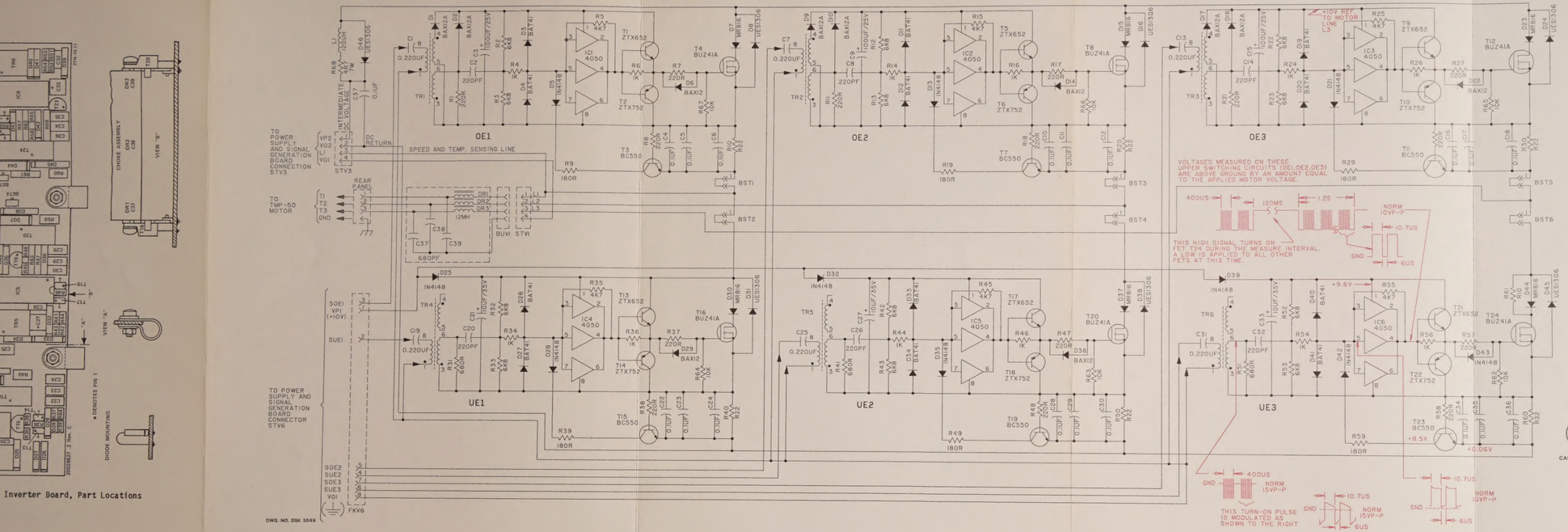


Figure 8-6. NT-50 Six Step Inverter Board, Part Locations

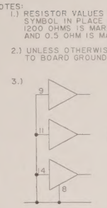


NOTES:

1.) RESISTOR VALUES ARE INDICATED BY PLACING THE MULTIPLIER SYMBOL IN PLACE OF THE DECIMAL POINT. FOR EXAMPLE : 1200 OHMS IS MARKED 1K2, 100 OHMS IS MARKED 100R, AND 0.5 OHM IS MARKED R5.

2.) UNLESS OTHERWISE SPECIFIED, ALL VOLTAGES ARE REFERENCED TO BOARD GROUND VO1.

3.)



WARNING

All measurements are referenced to board ground VO1 which is ABOVE chassis ground. If using AC powered test equipment, float its AC ground connection to prevent short circuiting the converter. Beware that the test equipment chassis will now be above earth ground by up to 160 volts!

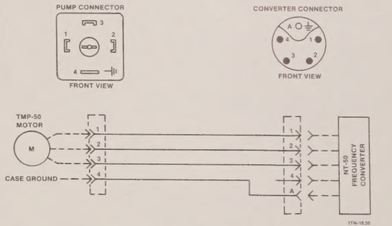


Figure 8-7. NT-50 Six Step Inverter Board, Schematic

Index

A

AC Voltage and Fuse Selection, 3-3
Additional Material, 2-2
Air Cooling Unit Installation, 3-18
Air Cooling Unit, 1-4
Automatic Venting Valve Installation, 3-19
Automatic Venting Valve, 1-5

B

Bakeout (CF Flange only), 4-8
Bakeout Jacket (CF Flange only), 1-3
Bakeout Jacket Installation, 3-21

C

Checking Pump Motor Direction of Rotation, 3-11
Control and Status Indication Board, 6-23
  Drive Frequency Clock, 6-30
  Drive/Measure Interval Clock, 6-24
  Output Disable Control, 6-26
  Overtemperature Failure Latch, 6-33
  Pump Speed to Current Converter, 6-27
  Pump Speed Monitor and Status Indication, 6-28
  Slip Dependent Voltage Regulator, 6-31
  Start/Stop Latch, 6-25
Converter Cooling, 3-5
Converter Mounting, 3-5
Converter Rear Panel Terminal Block
  Wiring, 3-7
Current Limiter, 6-16

D

Detailed Descriptions, 6-1
  Frequency Converter Basic Functions, 6-4
  NT-50 Circuit Descriptions, 6-12
   Control and Status Indication Board, 6-23
   Power Supply and Signal Generation Board, 6-12
   Six-Step Inverter Board, 6-34
  NT-50 Operating Principles, 6-6
  TMP-50 Construction, 6-2
  TMP-50 Operating Principle, 6-1
Drive Frequency Clock, 6-30
Drive/Measure Interval Clock, 6-24

E

Exhaust Port Connection, 3-16

F

Frequency Converter Basic Functions, 6-4

G

Grounding, 3-8

I

Initial Converter Wiring, 3-7
Installation, 3-1
  AC Voltage and Fuse Selection, 3-3
  Air Cooling Unit, 3-18
  Automatic Venting Valve, 3-19
  Bakeout Jacket, 3-21
  Checking Pump Motor Direction of Rotation, 3-11
  Converter Mounting, 3-5
  Converter Rear Panel Terminal Block Wiring, 3-7
  Exhaust Port Connection, 3-16
  Grounding, 3-8
  Intake Port Connection, 3-15
  Preliminary Installation Considerations, 3-1
  Pump and Converter Interconnection, 3-10
  Unpacking and Inspection, 2-1
  Water Cooling Unit, 3-18
Intake Port Connection, 3-15
Intermediate DC Voltage Monitor, 6-15
Intermediate Venting Flange, 1-6
Introduction, 1-1

L

Leak Test, 5-21

M

Maintenance and Adjustments, 5-1
  NT-50 Adjustments, 5-24
    +10 V Switching Power Supply Voltage
      Adjustment (P1), 5-26
    +7.5 V Reference Adjustment (P2), 5-26
    Maximum Drive Frequency Adjustment (P1), 5-29
    Pump Overtemperature Trip Point Adjustment
      (P1), 5-27
    Pump Speed Monitor Pulse Width Adjustment
      (P2), 5-30
  NT-50 Disassembly, 5-23
  Preventive Maintenance, 5-1
  TMP-50 Cleaning, 5-2
  TMP-50 Disassembly/Reassembly, 5-6
Maximum Drive Frequency Adjustment (P1), 5-29
Motor Housing Removal, 5-8

N

NT-50 Adjustments, 5-24
  +10 V Switching Power Supply Voltage Adjustment
    (P1), 5-26
  +7.5 V Reference Adjustment (P2), 5-26
  Maximum Drive Frequency Adjustment (P1), 5-29
  Pump Overtemperature Trip Point Adjustment
    (P1), 5-27
  Pump Speed Monitor Pulse Width Adjustment
    (P2), 5-30
NT-50 Circuit Descriptions, 6-12
  Control and Status Indication Board, 6-23
  Power Supply and Signal Generation Board, 6-12
  Six-Step Inverter Board, 6-34
NT-50 Disassembly, 5-23
NT-50 Front Panel Controls and Indicators, 4-1
NT-50 Installation, 3-3
  AC Voltage and Fuse Selection, 3-3
  Checking Pump Motor Direction of Rotation, 3-11
  Converter Cooling, 3-5
  Converter Mounting, 3-5
  Converter Rear Panel Terminal Block Wiring, 3-7
  Grounding, 3-8
  Pump and Converter Interconnection, 3-10
NT-50 Operating Principles, 6-6
NT-50 Optional Equipment, 1-7
NT-50 Schematics, 8-5, 8-7, 8-9

O

Operation, 4-1, 4-4
  General Information, 4-1
  NT-50 Front Panel Controls and Indicators, 4-1
  Starting, 4-2
  Stopping, 4-6
  Venting, 4-7
  Bakeout (CF Flange Only), 4-8
Output Disable Control, 6-26
Overloads, 4-4
Overtemperature Failure Latch, 6-33
Overtemperature, 4-5

TMP/NT-50
Turbomolecular Pump & Frequency Converter

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